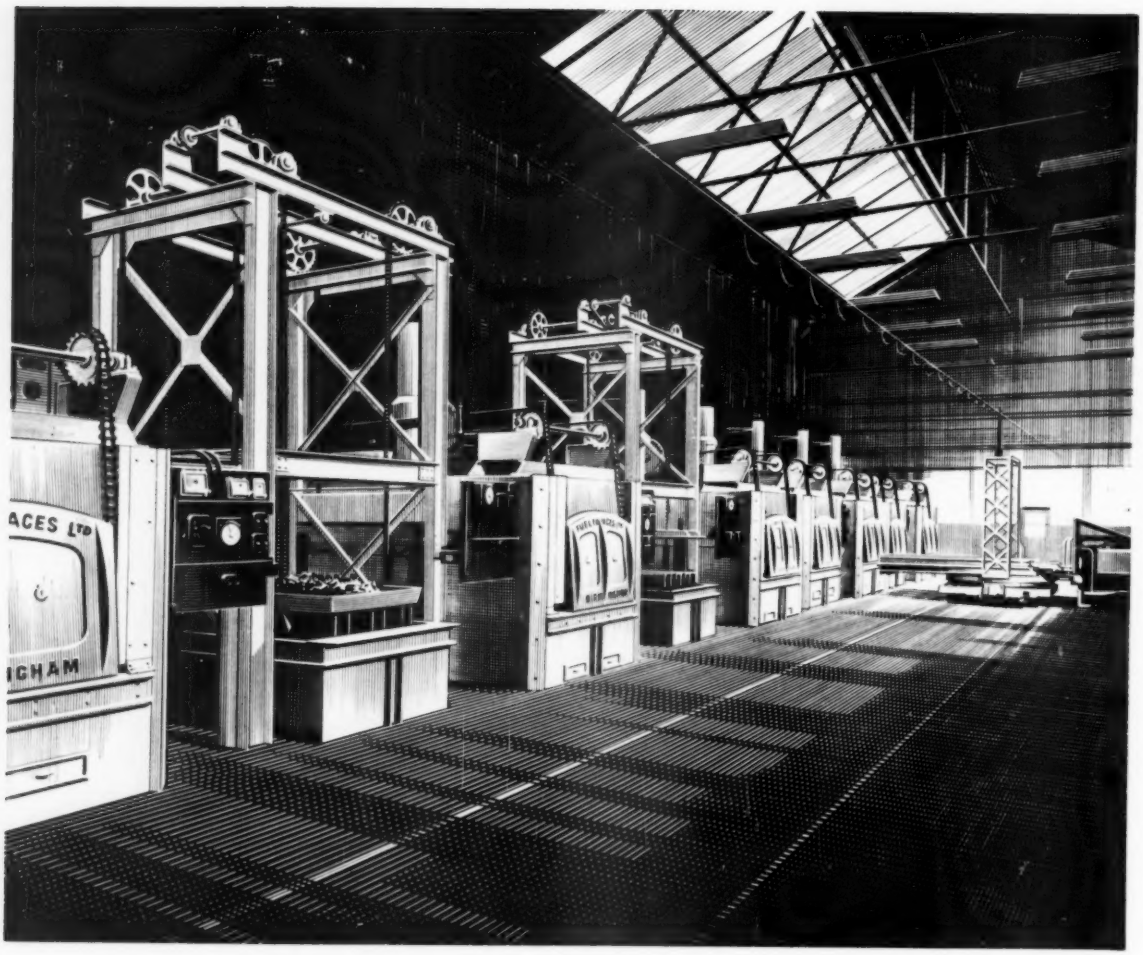
METALLURGIA

THE BRITISH JOURNAL OF METALS

Vol. 59 No. 352 FEBRUARY, 1959 Monthly: Two Shillings and Sixpence

'MODERN MALLEABLE' (*2nd Edition*). If you have not had a copy, kindly send us a P.C. We shall be pleased to forward one, post free.

'MODERN MALLEABLE' (2nd Edition). If you have not had a co



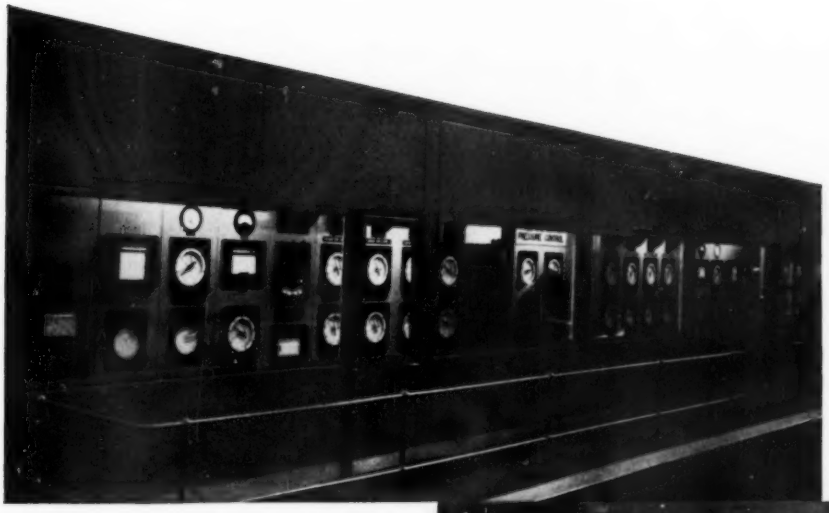
Impression by courtesy of Messrs. Hum ıer Ltd.

HEAT TREATMENT of forgings

Furnaces and Equipment designed and built by

Fuel Furnaces Ltd

SHADY LANE · GREAT BARR · BIRMINGHAM 22A



120 tons of steel an hour
raised to rolling temperatures under the control of Honeywell instruments at the new Brinsworth mill of Steel Peech and Tozer Ltd. The system ensures desired temperature distribution, with maximum fuel economy.

8,700 gallons of petroleum an hour
processed under Honeywell control at the British Petroleum Company's new thermal reforming plant on the Isle of Grain. Honeywell instruments ensure accurate fractionation and good high-octane yields.

on such a scale

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In steel . . . petroleum . . . and every major industry, automatic controls by Honeywell are now *built in* to new large-scale processing plant. Comprehensive systems—composed of miniature or conventional instruments—are engineered and supplied as completely piped and wired panels ready for installation. When in action, each control system—designed and built *for the plant* from interlocking standard Honeywell units—maintains a complex of process conditions at a stable optimum as accurately as a single instrument for one variable.

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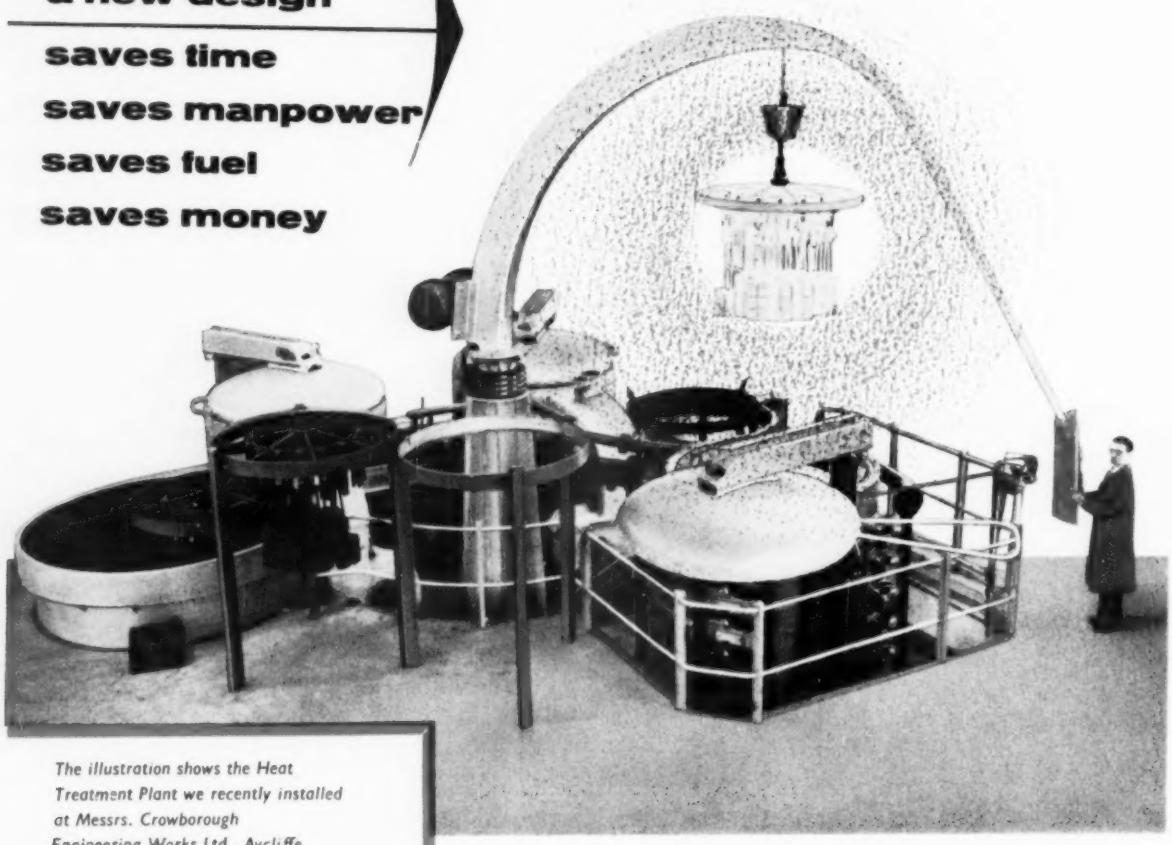

The illustration shows the Heat Treatment Plant we recently installed at Messrs. Crowborough Engineering Works Ltd., Aycliffe.

The complete unit installation at Aycliffe consists of Hardening Furnace, two Tempering Furnaces, Water Quench Tank, Oil Quench Tank, Loading and Unloading Racks. The unit is serviced by a fully-automatic, centrally-located, electrically-operated crane. The two re-circulating Tempering Furnaces utilise the waste heat from the Hardening Furnace. Supplementary gas is automatically provided when necessary.

Further details are available on enquiry to :—

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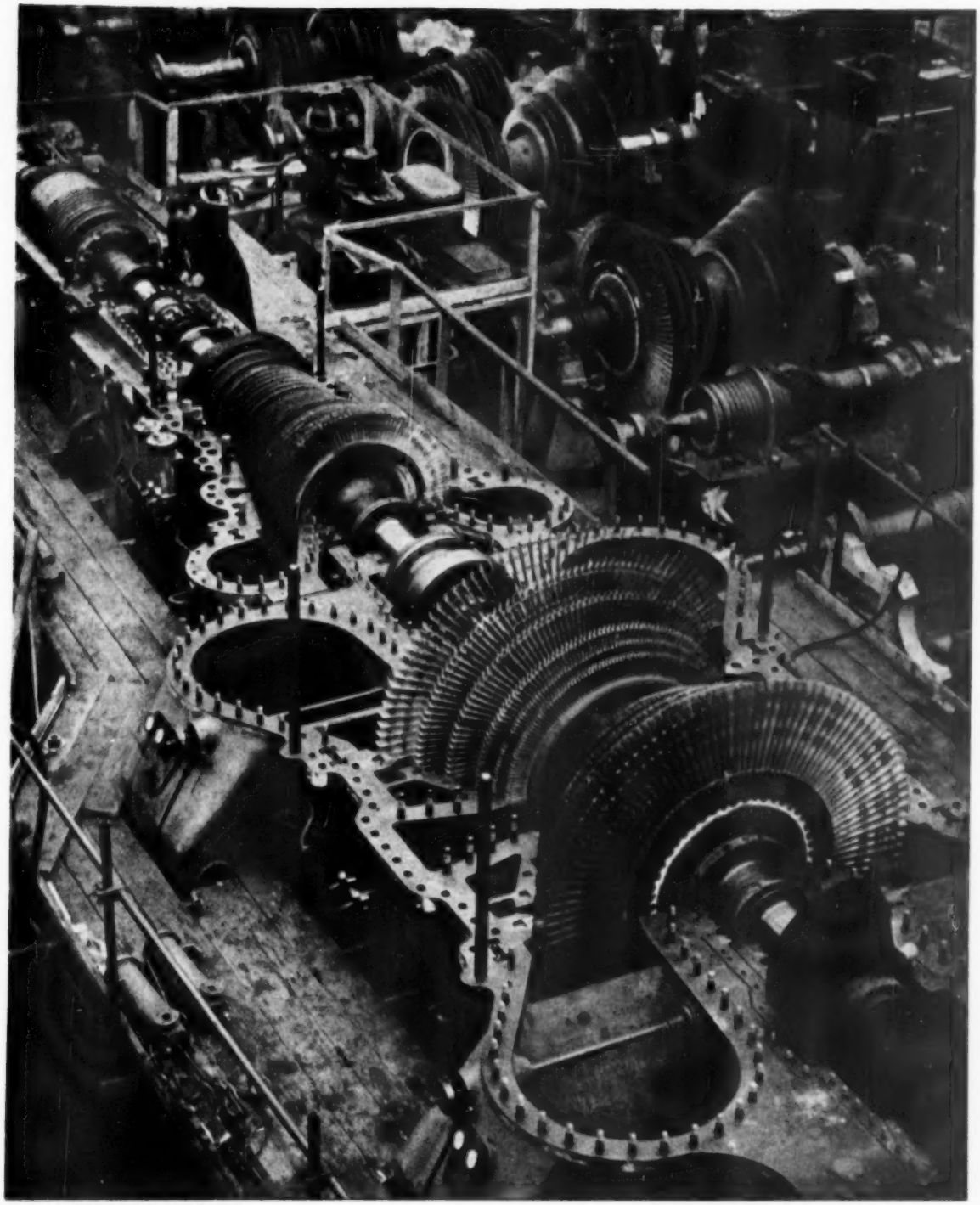

TURBINE ROTOR FORGINGS

Turbo-Generator under construction at C. A. Parsons & Co., Ltd.

by

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Different temperature ranges call for different alloy combinations—and we provide them, including 'T1/T2', the only British-made base metal thermocouple for temperatures up to 1100°C. In cases where thermocouple wires are covered by a British Standard we produce them to conform to the Standard.

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T1/T2 are wires of the nickel-chromium/nickel-aluminium type for use at high temperatures and conform to the British Standard Specification 1827: 1952 within the usual tolerances. They also meet the requirements laid down in Air Ministry Specifications 1632 and 1705 covering extension leads.

Special Advance* wire (60/40 copper-nickel) is for use with copper up to 400°C and with iron up to 900°C. The EMF requirements of these two combinations vary according to individual specifications. Special Advance* wires can be selected in most cases to meet these varying demands within the usual tolerances.

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If you are interested in thermocouple alloys, then you may like to have a copy of Data Sheet No. 2, for reference.

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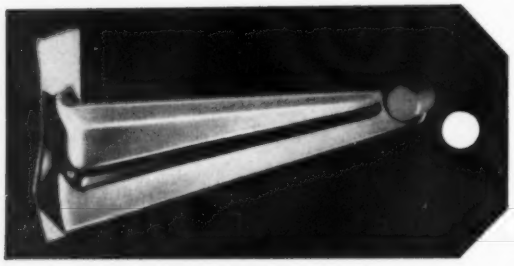

The Birmal foundries produce sand and gravity die castings in aluminium and magnesium alloys, and pressure die castings in aluminium, magnesium and zinc alloys for use in practically every industry.

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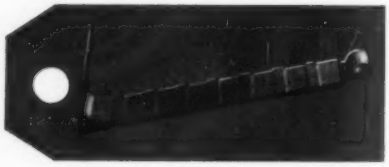

BIRMID WORKS
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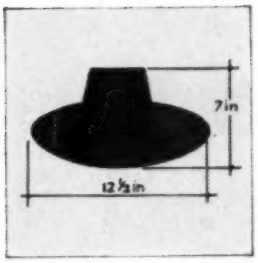

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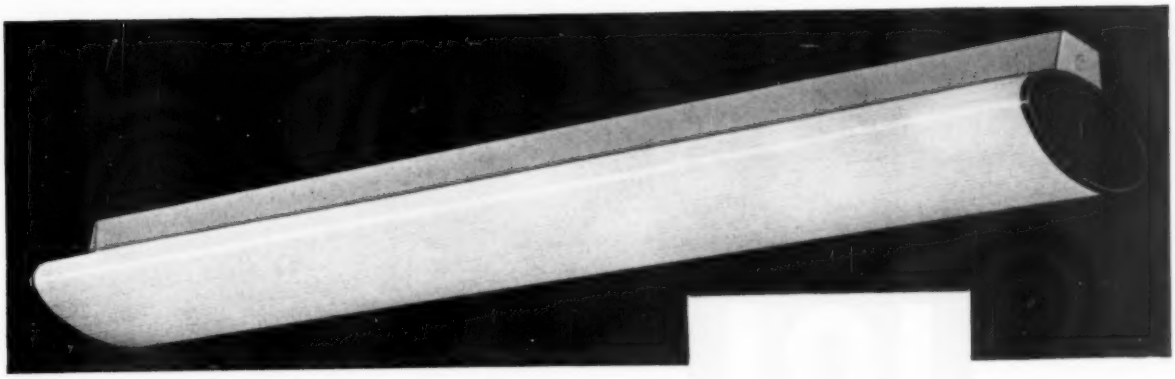
The fitting illustrated F41124/5 consists of a standard channel with an enclosed diffuser in reeded 030 'Perspex' with black ends and polished brass trim.



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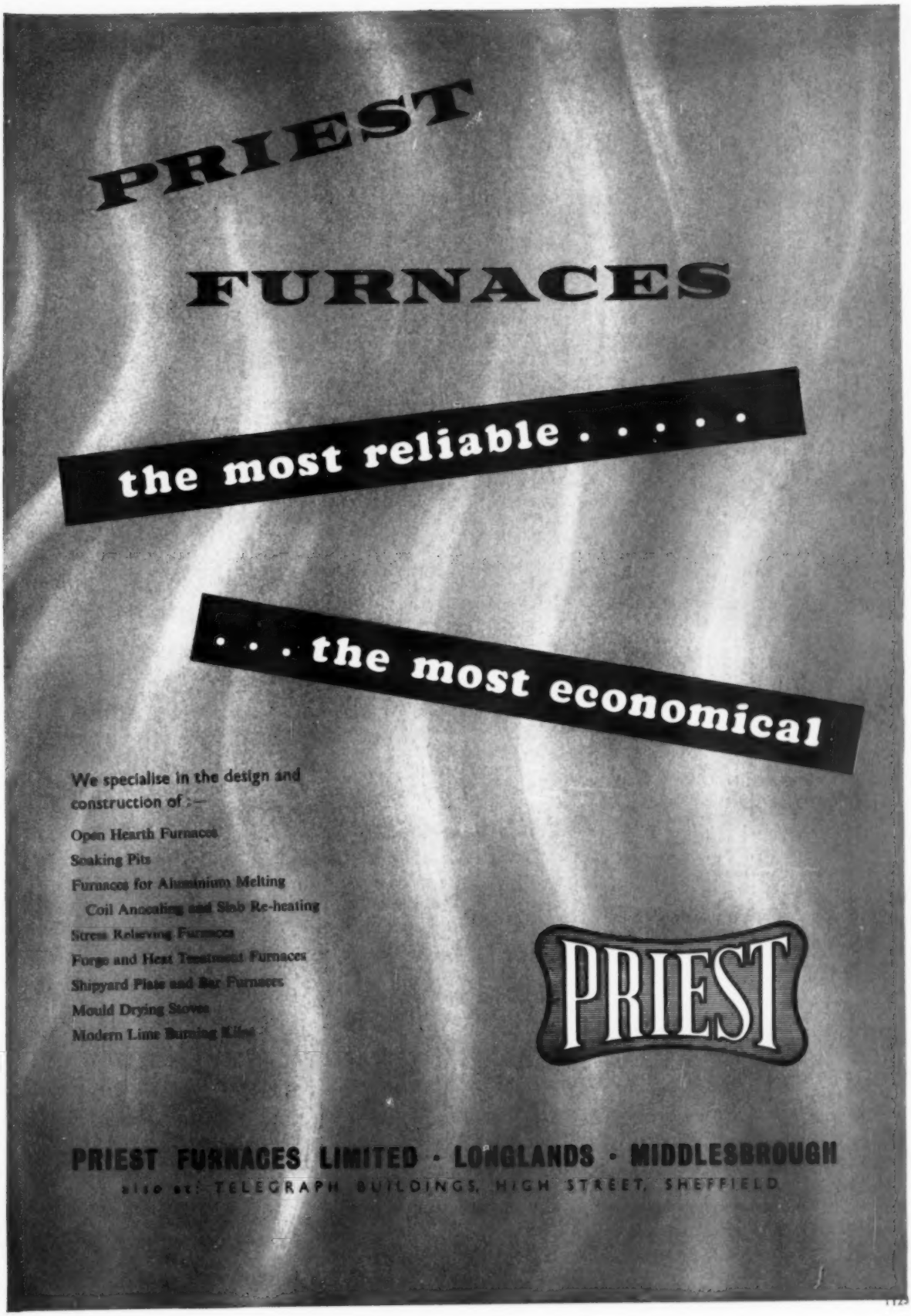
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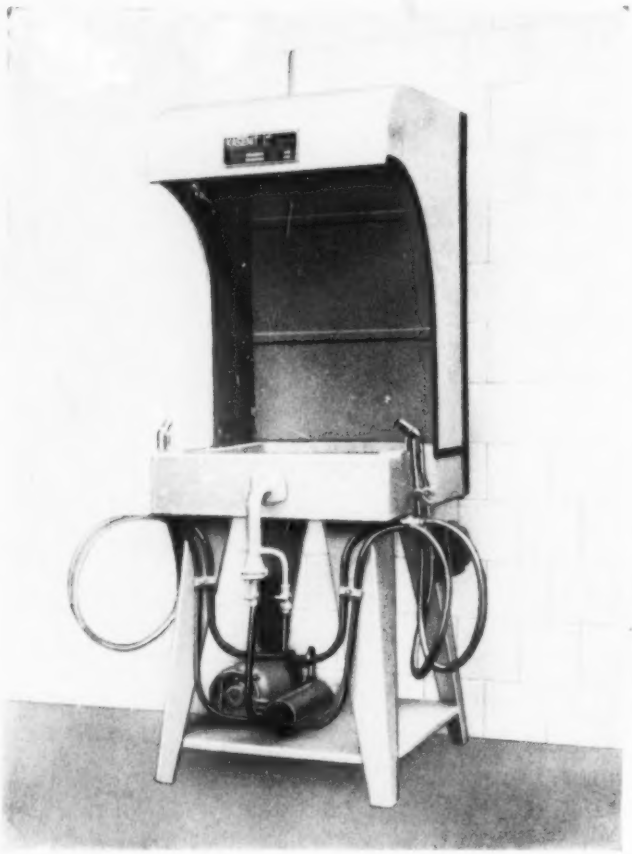

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Complete with Motor Driven Positive Air Blower, two Gas Blast Blow Pipes and one Gas Blast Burner. Suitable for Tube bending up to 1 in. diameter.

Size of Hearth, 20 in. × 20 in. × 4 in.

Gas Consumption, 200 cu. ft. per hour maximum.

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Suitable for temperatures up to 900° C.

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Time to heat up—1½ hours.

Manufactured by

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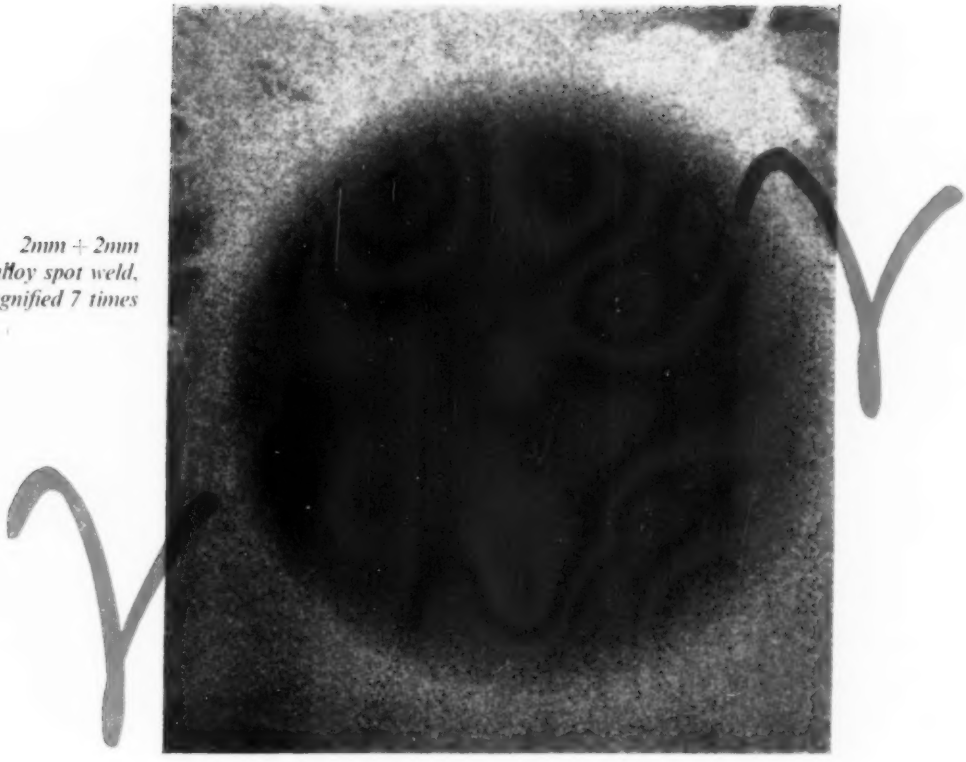

2mm + 2mm light alloy spot weld, magnified 7 times

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ILFORD CX INDUSTRIAL X-RAY FILM

This new addition to the range of Ilford Industrial X-Ray films will give greatly improved radiographs of steel welds and light-metal castings. For examinations at up to 200 kVp it is twice as fast as Industrial C and with gamma-ray techniques it is as much as three times as fast. Because of its higher contrast and finer grain, it gives better definition than is possible with Industrial B. The inherent high contrast of Ilford CX makes this new film extremely useful for radiography with 1- and 2-million volt apparatus as well as with gamma rays. Ilford CX Industrial X-Ray film may be used with or without lead screens. The recommended developer is Ilford PQX-1.

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. . . is British-produced material of the very highest quality. Coming from our Sheffield plant, it can, if necessary, be in your works the next day.

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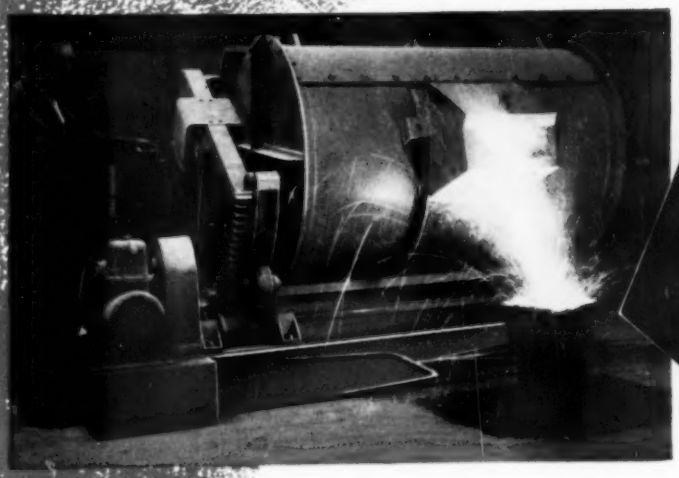
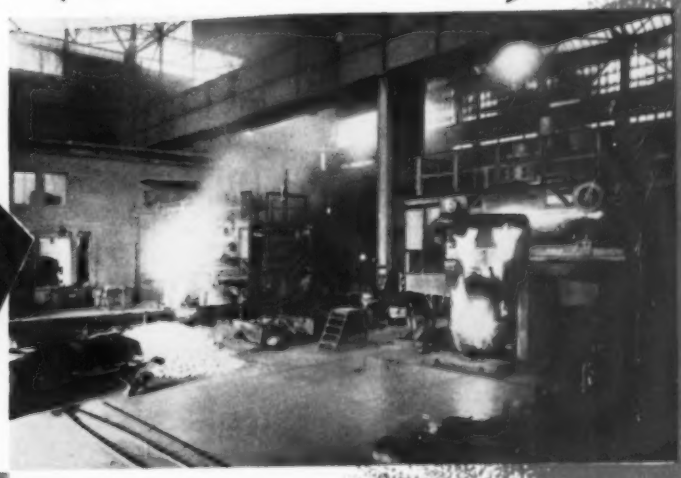


Mains Frequency
Light alloys, non-ferrous metals, S.G. irons, steel - all are melted in Metalectric-Calamari channel type induction furnaces. Directly connected to A.C. mains, this GRK 150 model is used for holding and superheating nickel-chromium alloys.

METALECTRIC *an essential part of the foundry*

Direct Arc
Two Metalectric 40 ton top charging direct arc steelmelting furnaces. Rated at 10,000 kVA, each furnace produces 960 tons of steel a week, using a double slag process. Other units, with capacities from 1 ton upwards, are in operation in iron, steel, and nonferrous foundries.



High Frequency
The Metalectric - Hewittic coreless induction furnace has been developed for melting all ferrous and non-ferrous metals in comparatively small quantities. This static convertor requires no special foundations, and is extremely simple to operate and maintain.

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DIAMOND ABRASIVE COMPOUND FOR METALLOGRAPHY

● Microfin Diamond Abrasive Compound is made in both water and oil soluble composition. Used for polishing Metallurgical specimens it is helping laboratory practice by bringing out the metal's pure characteristics without causing metal flow and by giving clear definition of grain boundaries, edges and inclusions. For instance, in cast iron, nodular and flake graphites are easily detected. Microfin achieves great economy in the laboratory in price as well as giving cleaner and quicker results.

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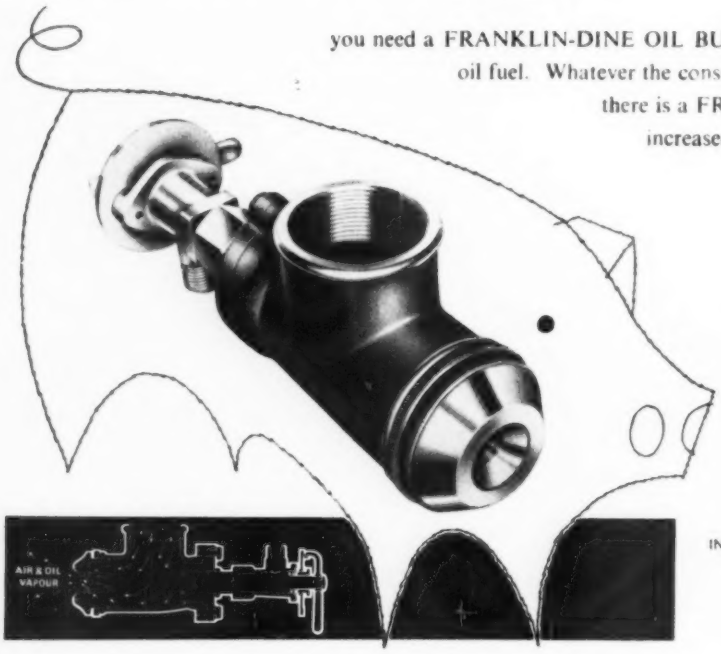
you need a FRANKLIN-DINE OIL BURNER to achieve immediate economy in oil fuel. Whatever the consumption, from ½th to 150 gallon per hour there is a FRANKLIN-DINE OIL BURNER to give increased oil economy at lower maintenance cost Write to-day for full particulars.



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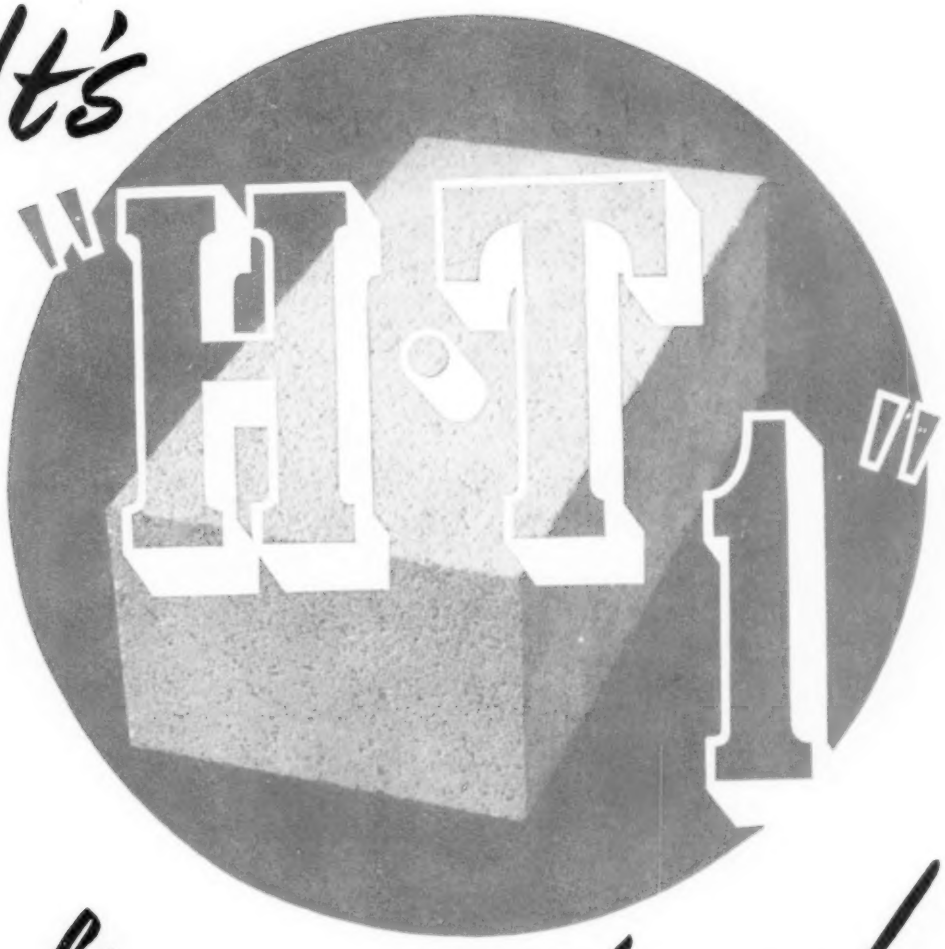

from experience!

From experience Gibbons "H.T 1" insulating refractory is the automatic choice of leading furnace manufacturers and users — its combination of low thermal conductivity with resistance to high temperatures has proved remarkably effective in minimising heat losses and raising furnace outputs. The Gibbons "H.T 1" is developed from more than 20 years' experience in the manufacture of insulating refractories and today an entirely new and original manufacturing technique enables us to offer material having unique physical properties at a price you can afford to pay.

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B T-H

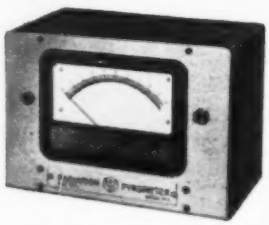
INFRA-RED RADIATION

PYROMETER

measures temperatures from 150°C to 2000°C

Measuring and recording temperatures during lathe glass-working operations.

Viewing head of BTH Infra-red pyrometer, cover removed.



Control and indication unit.

This versatile instrument provides a ready means of ascertaining the temperature of stationary or moving objects by measuring the intensity of infra-red radiation emitted from a surface, the viewing area of which can be as little as 0.4 in. diameter.

Light in weight due to the use of transistor amplifier circuits, and easy to set up and operate, the pyrometer lends itself to a wide range of industrial applications, including production-line testing.

SOME TYPICAL USES

Steelmaking—Temperature measurement of strips, bars, ingots.
Rolling Mills—Checking roll temperatures.
Motor Industry—Checking temperatures of brake discs or shoes.
Railway Engineering—Temperature checks on wheels, brakes, axle-boxes.
Metallurgical—Measuring temperatures of furnace 'melts', or of metals in dipping tanks.
Glass Manufacture—Checking temperatures during fusing, cutting and annealing.

Please write for leaflet DL5862-1.

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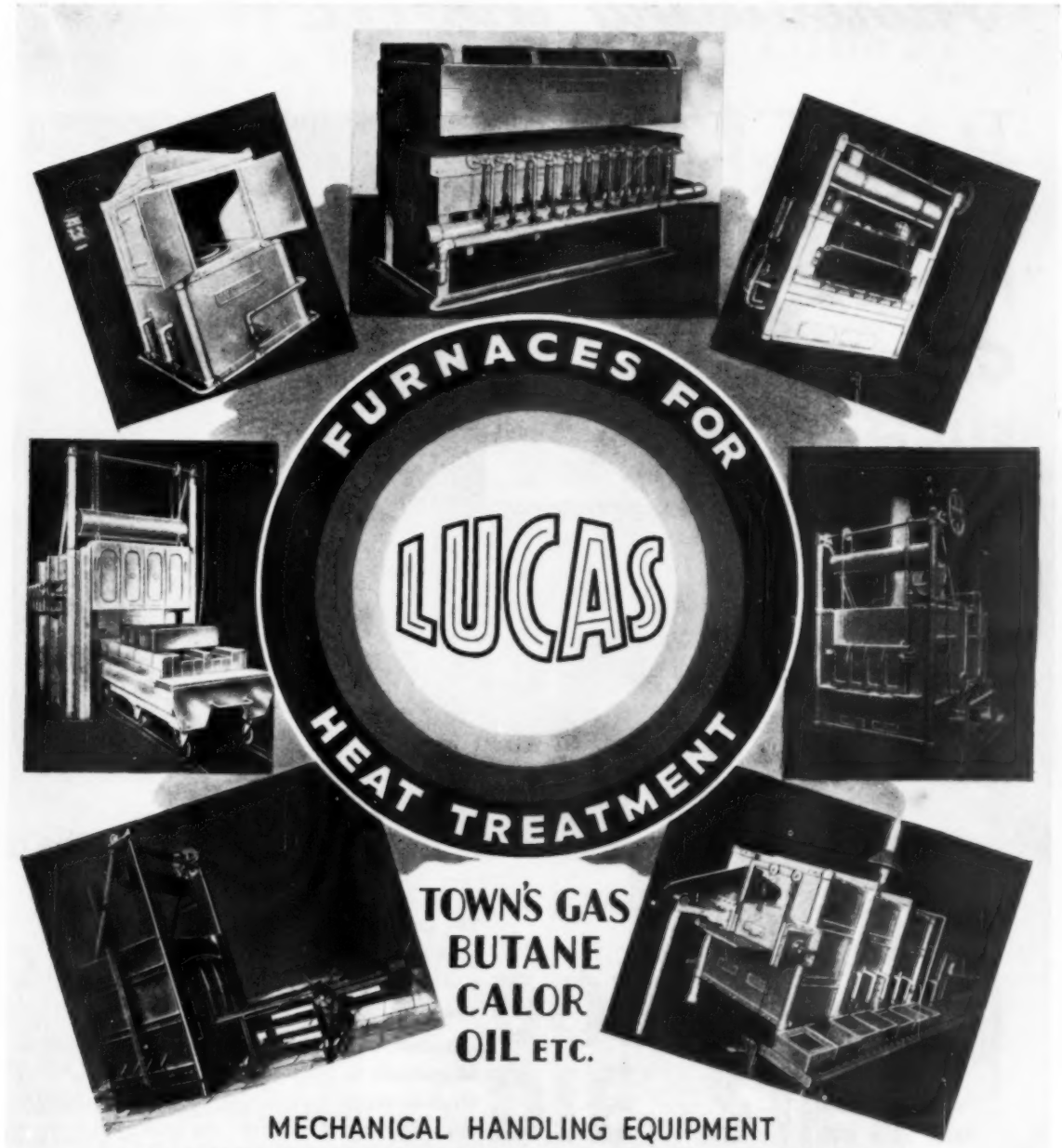

MECHANICAL HANDLING EQUIPMENT
AND MILD STEEL FABRICATIONS OF EVERY DESCRIPTION.

LUCAS FURNACES LIMITED

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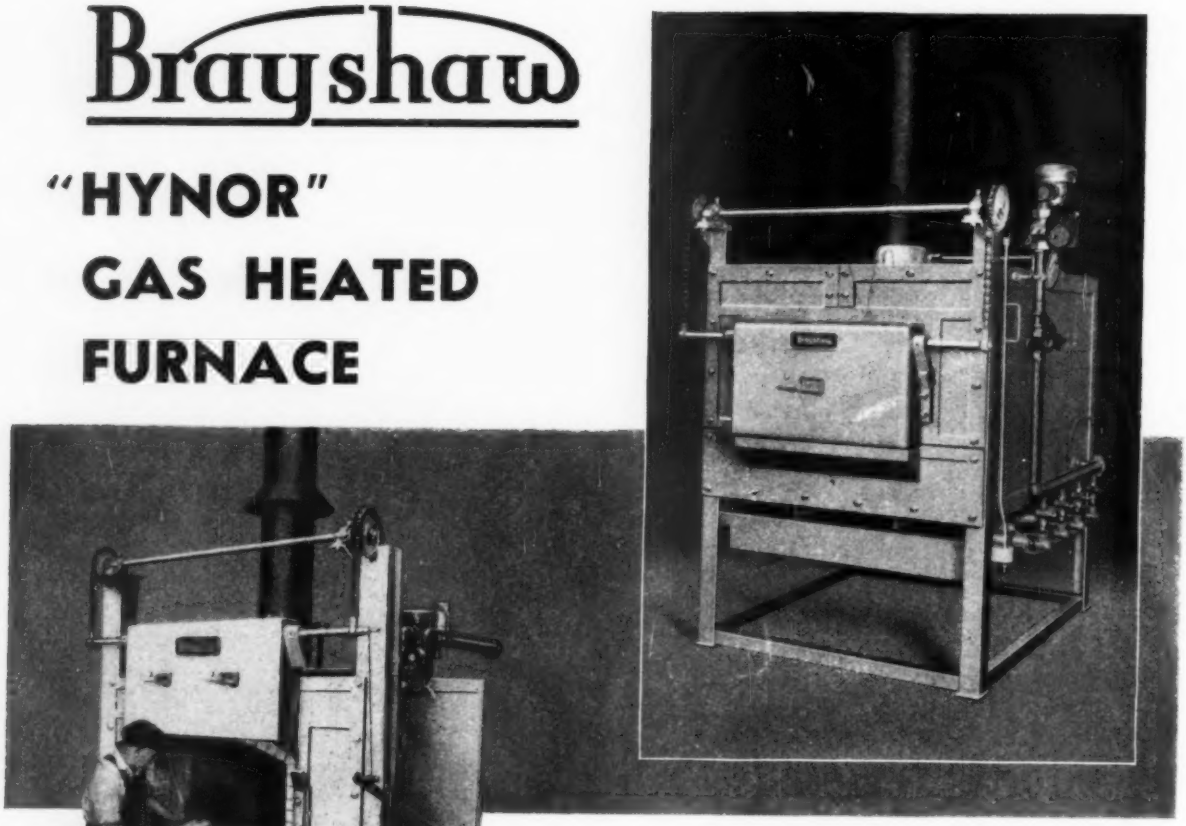
Introducing the NEW...

Brayshaw

"HYNOR" GAS HEATED FURNACE



The Brayshaw Hynor marks a new development in gas fired furnace design and fulfils requirements for a wide range and highly efficient general heat treatment furnace.

Designed for simplicity of operation with pre-set adjustments for easy control the Brayshaw Hynor Oven heated by natural draught burners is available in a wide range of standard sizes for the temperature ranges 650/1200°C.

For further details ask for a copy of our leaflet A1/58.

Brayshaw FURNACES LIMITED

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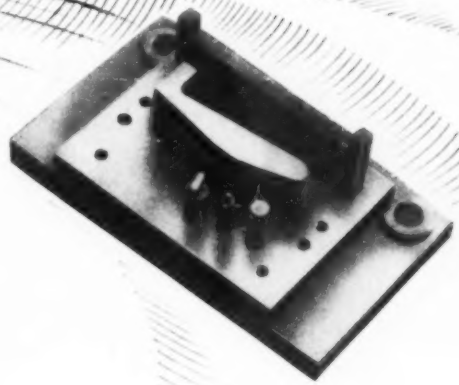
DOUBLE SIX

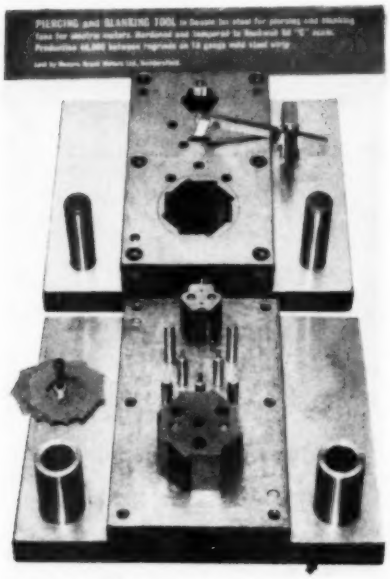
for long runs . .



For specially long runs or whenever the duty is very severe, Double Six Super Die Steel is recommended—the somewhat higher cost is recovered many times over in the extra production life of the tool.

The highly alloyed composition gives it a cutting edge which will last longer than ordinary die steels ; it is non-shrinking, and suitable for intricate sections.

Our records show some outstandingly long production runs achieved by this superior die steel. Write for full information.



PIERCING and BLANKING TOOL in Double Six steel for piercing and blanking fans for electric motors. Hardened and tempered to Rockwell 60 "C" scale. Production 40,000 between regrinds on 18 gauge mild steel strip. Photograph by courtesy of Messrs. Brook Motors Ltd., Huddersfield.

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PAYS IN THE LONG RUN

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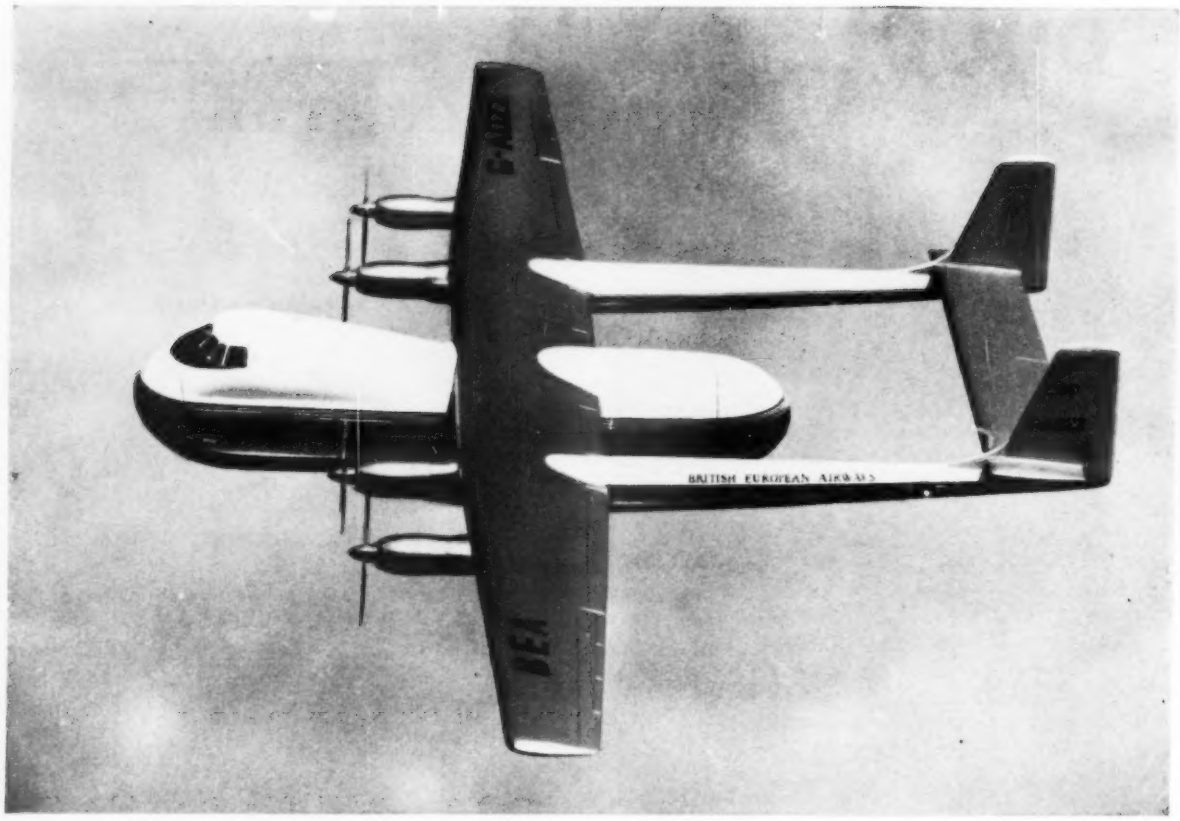

BRITISH ALUMINIUM

in the ARGOSY Freightercoach

The Argosy is the first true multi-purpose, pressurised, turbo-prop aircraft in the world. Designed for the economic carriage of freight, passengers or mixed traffic over medium stage routes throughout the world, the Argosy was developed specifically for operating at low cost, with ease of maintenance, reliability and real flexibility. British Aluminium, as materials suppliers to Sir W. G. Armstrong Whitworth Aircraft Ltd, are proud to be associated with this venture.

The BRITISH ALUMINIUM Co Ltd

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AP-172

Staffordshire Landscapes

"To stand on Church Hill, Wednesbury at night and gaze around at the busy scene of myriad fires belching forth like so many volcanoes, was a sight not to be easily forgotten".

These words by a Staffordshire Historian describe Iron-smelting in the Black Country a hundred years ago.

Now, Church Hill commands a different view. There are too few furnaces today to turn the night sky glowing red, though combined output many times exceeds the awe-inspiring labours of a century ago.

The Black Country, where the early Iron-Masters wrought their successive legacies to Progress and darkened the sky, is turning green again. The scars of the old Iron-works have healed, a new power strides across the country-side from the distant generators and the smoke pall over the towns grows less and less.

Progress in Staffordshire, bringing almost every major improvement in the technique of iron-founding since 1700, is apparent in the landscape of the County as well as its products.

For almost a century and a half Pig Iron has been manufactured at Darlaston Iron Works. Today, the most modern methods of metallurgical control of raw materials and the finished product, enables them to supply Pig Iron of consistent uniformity to the most exacting specification.

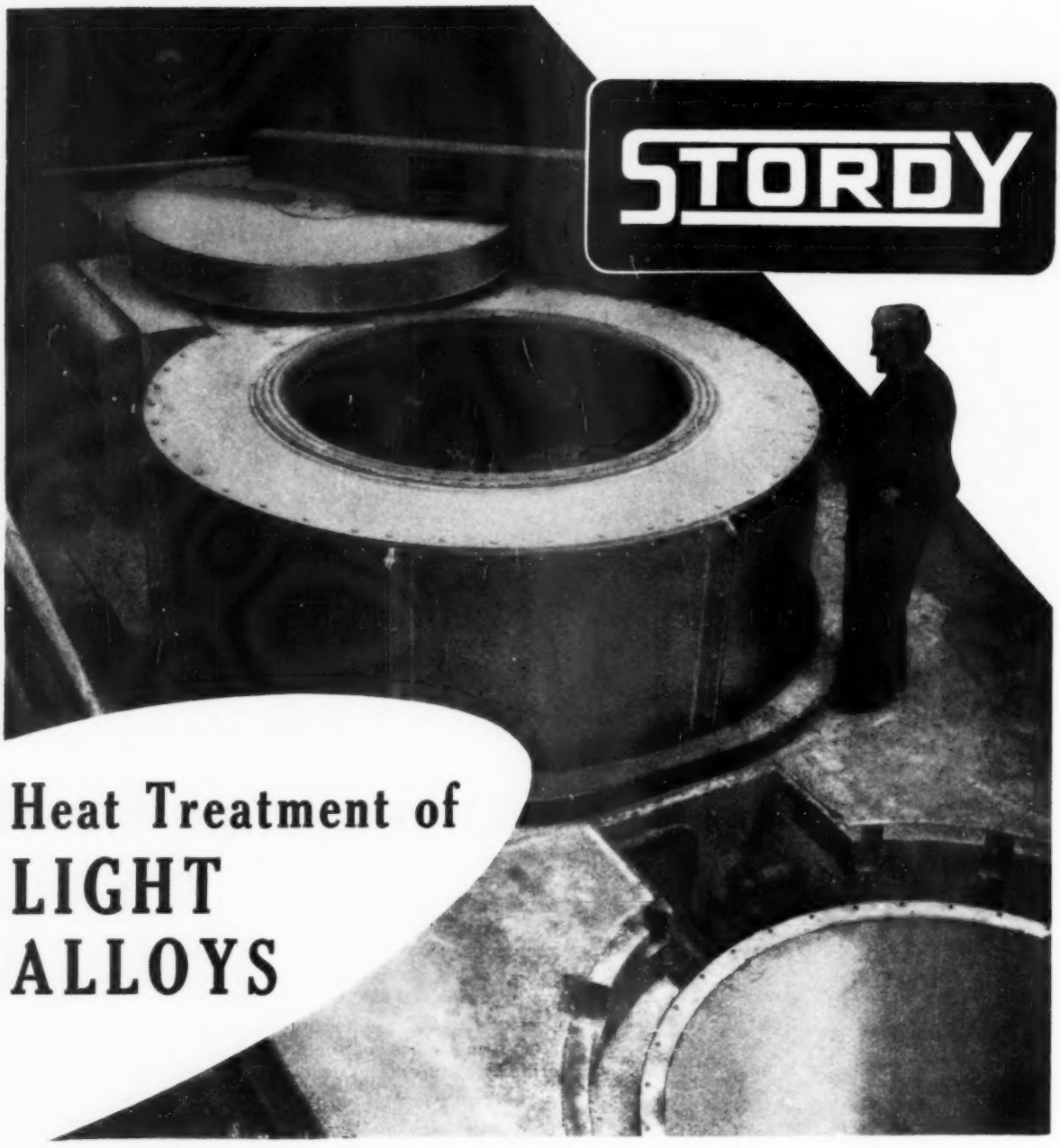
Bradley & Foster
LIMITED

FOR QUALITY-CONTROLLED
REFINED PIG IRON

DARLASTON · STAFFORDSHIRE

A member of the Staveley Coal & Iron Co., Ltd., Group.

L.G.B



Heat Treatment of LIGHT ALLOYS

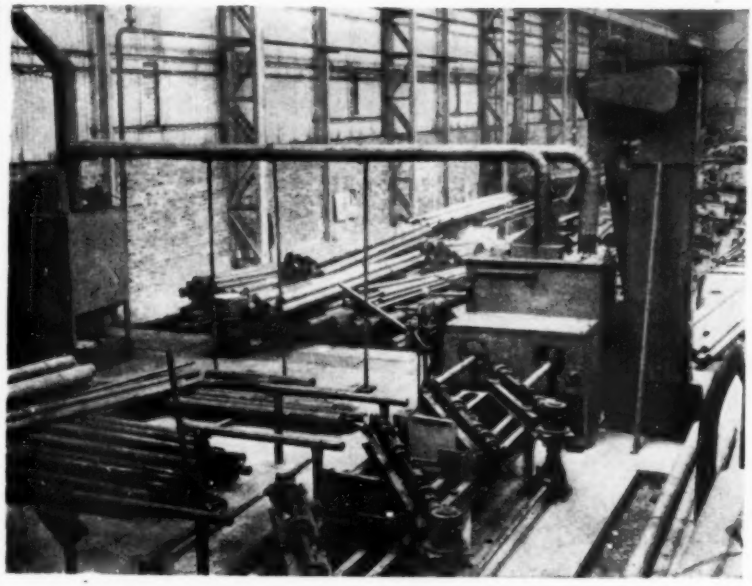
Greater efficiency, more precise control, higher output with considerably less maintenance and running costs—these are the features that place these STORDY Electric Furnaces ahead for light alloy treatment. Unit construction of heater battery allows ready derating adjustment for precipitation treatment and annealing—with same precise temperature control. In addition, the heater battery is remote from the furnace chamber and therefore easily accessible for inspection without dismantling. The large capacity centrifugal fan gives greater air circulation.

The furnace illustrated is for the heat treatment of extruded sections—work dimensions 5 ft. diameter by 8 ft. deep.

STORDY ENGINEERING LIMITED
CUMBRIA HOUSE · GOLDTHORN HILL · WOLVERHAMPTON

SM/SE 2807

JACKMAN FOR SPECIAL PURPOSE SHOT BLAST EQUIPMENT

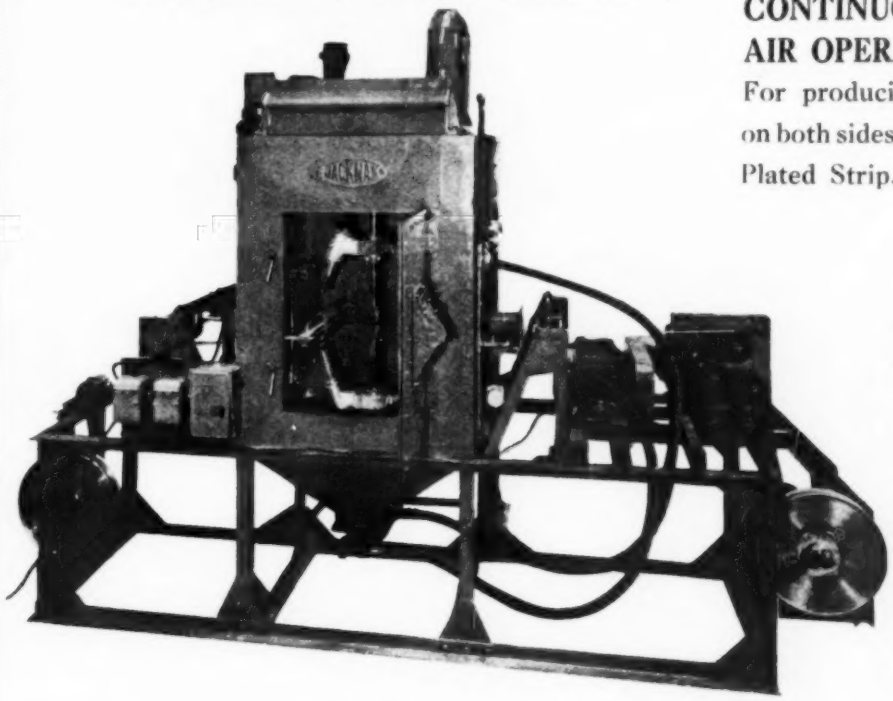


Photograph by kind permission of Weldless Steel Tube Co. Ltd., Wednesfield

AIRLESS PLANT WITH A SINGLE IMPELLOR

Cleaning two tubes simultaneously. The tubes are rotated and traversed by rollers. The plant is suitable for tubes from 2 ins. dia. to 10 ins. dia.

Rate of cleaning:—
20 sq. ft. per minute



CONTINUOUSLY ACTING AIR OPERATED PLANT

For producing a matt surface on both sides of Nickel or Nickel Plated Strip.

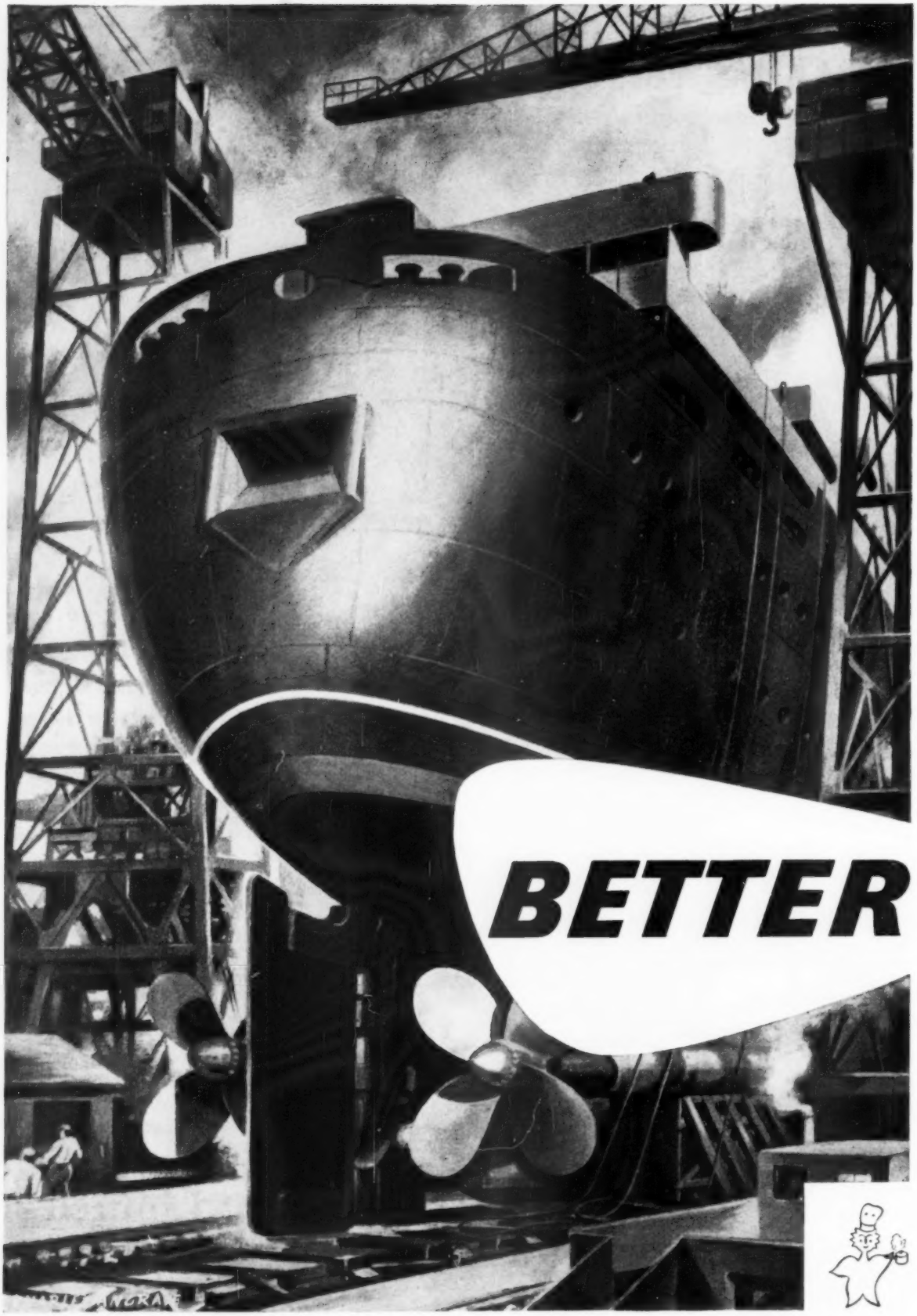
The equipment is complete with Coiling Gear.

We shall be pleased to quote for special plant to meet your needs.

J. W. JACKMAN & Company Limited

VULCAN WORKS · BLACKFRIARS ROAD · MANCHESTER, 3

Telephone: DEAnsgate 4648-9 *Telegrams: Blast, Manchester*


BETTER

Issued by the Gas Council

Production Standards...

. . . on Land, at Sea, and in the Air,
would not be possible without
Mr. Therm's **HEATSERVICE** to Industry

MR. THERM *BURNS* TO SERVE YOU *ALWAYS*
in all ways

AND – 11 million housewives cook by GAS !

Quality Control

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A Philips X-ray spectrographic attachment and wide angle goniometer. Used in conjunction with the well known high voltage generator PW.1010 and associated electronic circuit panel with recorder. (Products of N.V. Philips, Eindhoven.)

X-ray Spectrography has proved to be the economical answer to many problems of quality control and industrial analysis. Most industrial materials are amenable to analysis by X-ray Spectrography, which can be so highly automated that relatively unskilled labour can be employed.

This application service for industry has helped many . . . it may help you too!

Your most obstinate problem of quality control may possibly be solved by the unique properties of X-ray spectrography. Arrangements have been made between Research & Control Instruments Ltd. and N.V. Philips, Eindhoven, whereby the experience and facilities of the world-famous Philips X-ray analysis laboratories can be placed at your service. The problem will be studied by specialists and their conclusions can be discussed in your own works. This service is entirely free. Write to us now.

Many famous firms rely on Philips X-ray Spectrographic and Diffraction Equipment in their works and laboratories. And their choice has been guided by Philips outstanding achievements in this field.

A 60-page brochure describing the current range of equipment and its many applications is available on request from

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YOU CAN'T DISMANTLE A TRADITION

Iron was first made at Brymbo in 1798; steel in 1885. This year sees a further landmark—the dismantling of the open hearth steel furnaces. At the time of their installation these furnaces were unique in the United Kingdom. Now they give way to all-electric plant. Brymbo Steel Works Ltd., are now one of the largest producers of electrically melted steels in the country and the tradition of doing a good job supremely well is as strong as ever. After 160 years, that is one thing that cannot be dismantled.

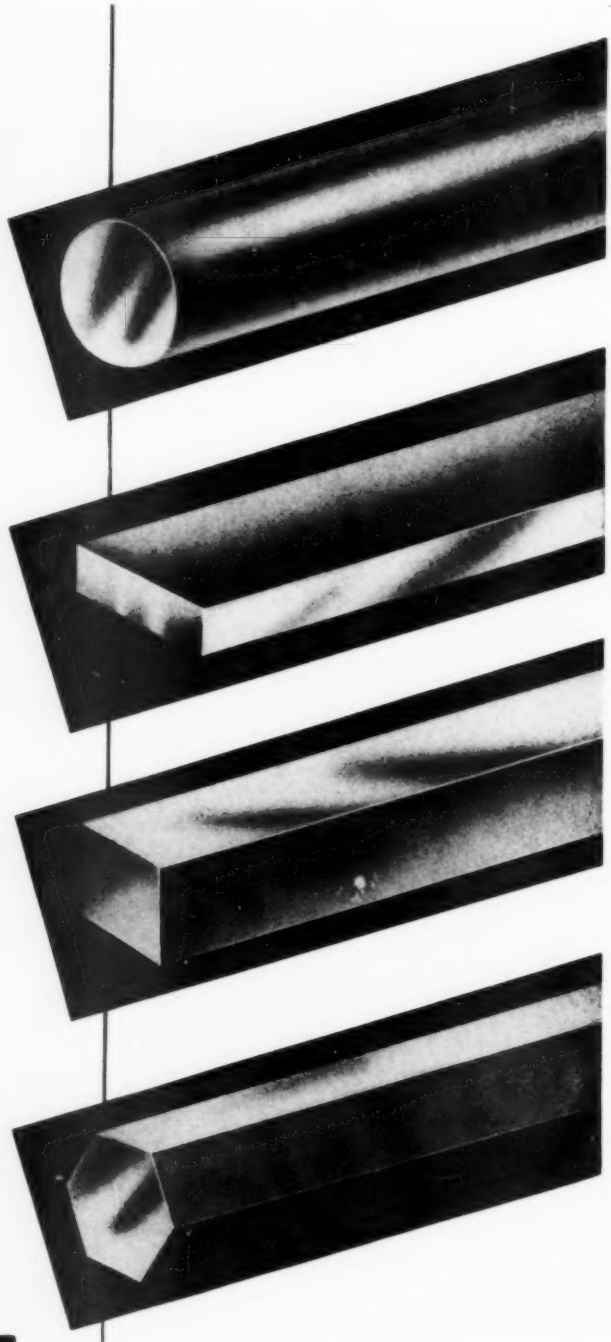
THE BRYMBO RANGE *of slabs and billets covers all types of low alloy and special carbon steels, including silico-manganese.*

Brymbo Steel Works Ltd.

BRYMBO · NR. WREXHAM · DENBIGHSHIRE

(One of the GKN Group of Companies)

Dependability and Quality in Dunelt Special purpose Alloy and Carbon Steels



Black rolled, bright drawn or smooth ground, in heat-treated or unheated conditions. Free cutting steels, heat-resisting steels, die steels, shear blade steels, high-speed tool steels, stainless steels, valve steels, hollow steel bars.

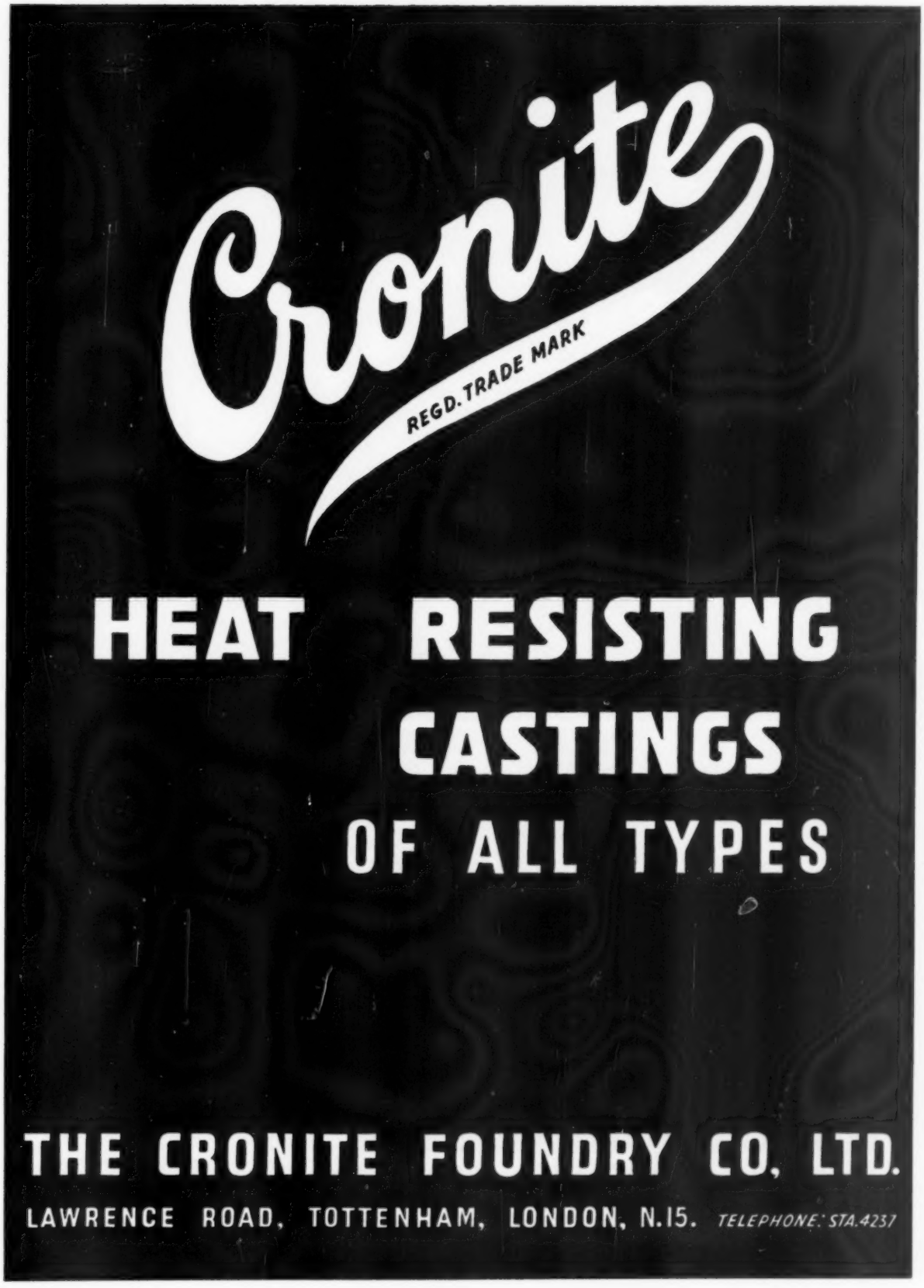
Dunelt

DUNFORD & ELLIOTT (SHEFFIELD) LTD
ATTERCLIFFE WHARF WORKS, SHEFFIELD 9

Telephone: 41121 (5 lines)
Telegrams: Blooms, Sheffield, 9

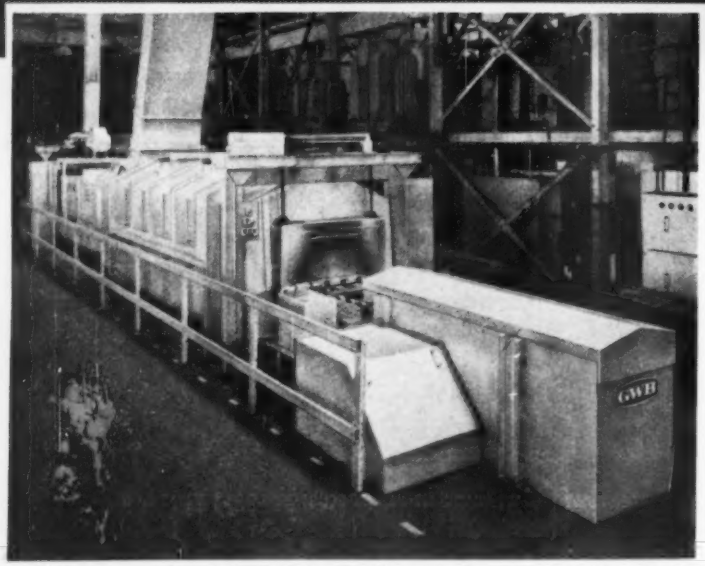
London Office: Linford Street, S.W.8

Birmingham Office: 25 Burlington Chambers, 118 New Street, 2


Cronite
REGD. TRADE MARK
HEAT RESISTING
CASTINGS
OF ALL TYPES
THE CRONITE FOUNDRY CO. LTD.
LAWRENCE ROAD, TOTTENHAM, LONDON, N.15. TELEPHONE: STA.4237

ALBION MOTORS AND G.W.B.

One of the oldest manufacturers of commercial motor vehicles in this country, Albion Motors keep up to date in their manufacturing methods by installing the latest and most efficient equipment available. An example is the electrically heated Pusher Furnace supplied by G.W.B. Furnaces Limited.



Overall view from charging end of 145 kw Pusher Type Normalising Furnace at Albion Motors Limited

APPLICATION

Various forgings such as main shafts, countershafts, pinion shafts and gear blanks are normalised by heating up to 900° C. and slow cooled down to 400/500° C.

AUTOMATIC OPERATION

The only labour required is for placing the components into the charge trays at the entrance end of the furnace. By pressing a button, the following cycle automatically takes place. (1) The entrance door rises. (2) The pusher ram propels the loaded tray into the furnace. (3) The ram returns. (4) Entrance door lowers. (5) Exit door rises. (6) Hydraulically operated go-getter pulls last tray from exit end of furnace on to a cross conveyor. The cross conveyor moves the normalised parts to the top of an inclined roller track where the tray is unloaded by a tipper, and then returns empty to the entrance end of the furnace.

OUTPUT

600 lbs. of normalised forgings per hour.

Over 25 years experience in electric furnace design at your disposal.

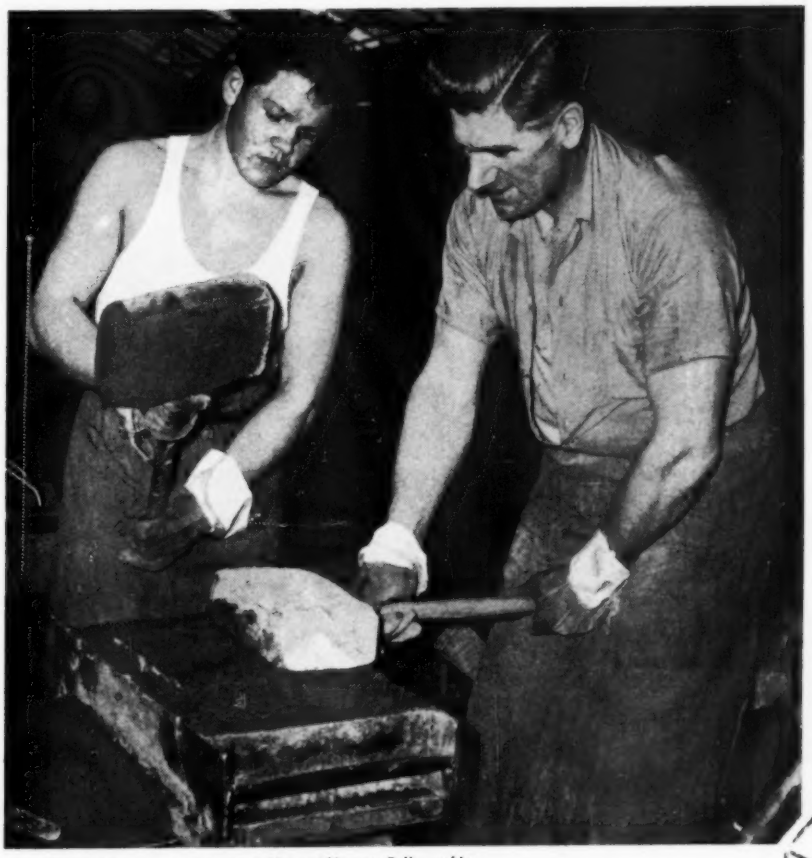
GWB

G.W.B. FURNACES LTD.

P.O. BOX 4, DIBDALE WORKS, DUDLEY, WORCS. TEL: DUDLEY 4284/5/6/7 & 5081/2/3/4/5.

Associated with: Gibbons Bros. Ltd. and Wild-Barfield Electric Furnaces Ltd.

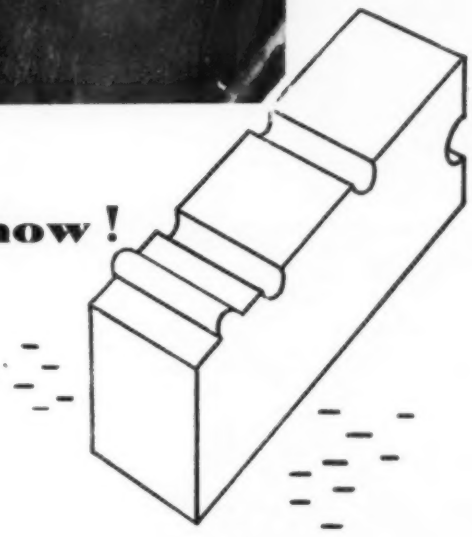
GWB213



George Devanney, assistant moulder and Norman Bell, moulder, beating the mixing into a mould with wooden mallets.

It's perfectly simple...

when you know how!



And in the course of the past 80 years a great deal of 'know how' about refractories of all kinds has been accumulated at Consett.

- *You may care to write for a copy of the Company's new booklet describing all its refractory products.*

CONSETT IRON COMPANY, LIMITED
CONSETT · COUNTY DURHAM · ENGLAND

Telephone: Consett 341 (12 lines)

Telegrams: STEEL PHONE, Consett

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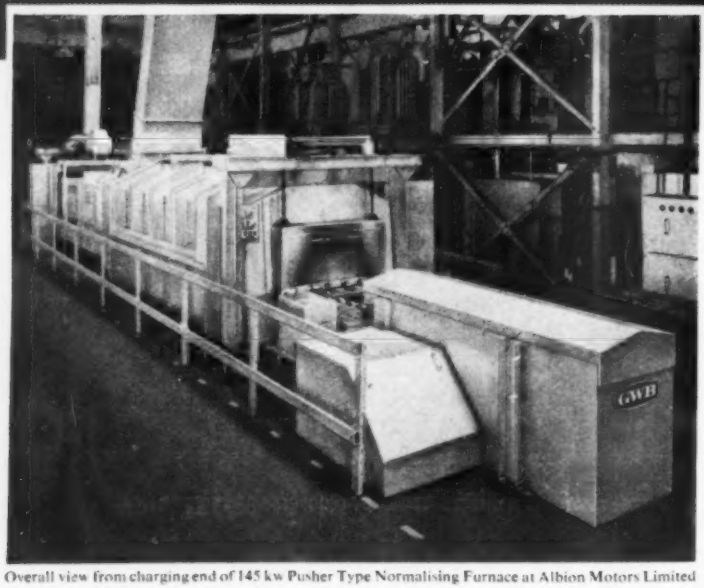

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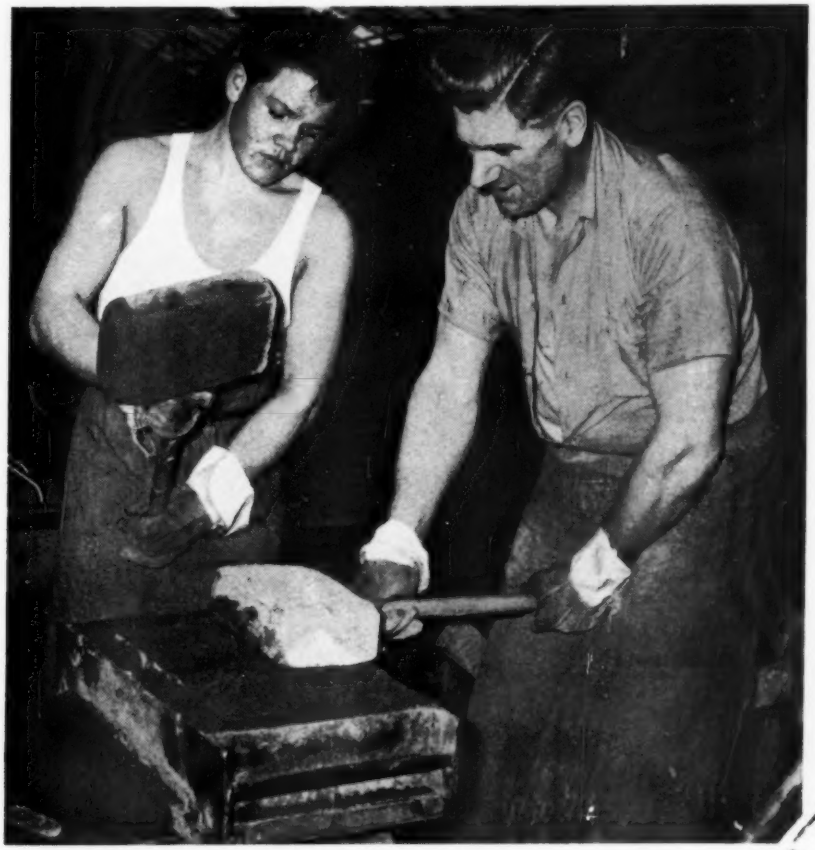
Associated with: Gibbons Bros. Ltd. and Wild-Barfield Electric Furnaces Ltd.

GWB215



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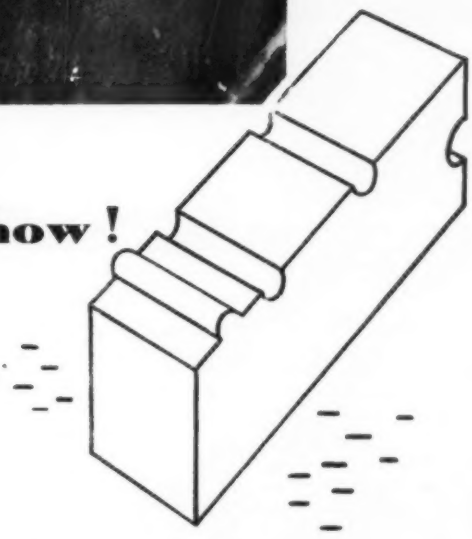

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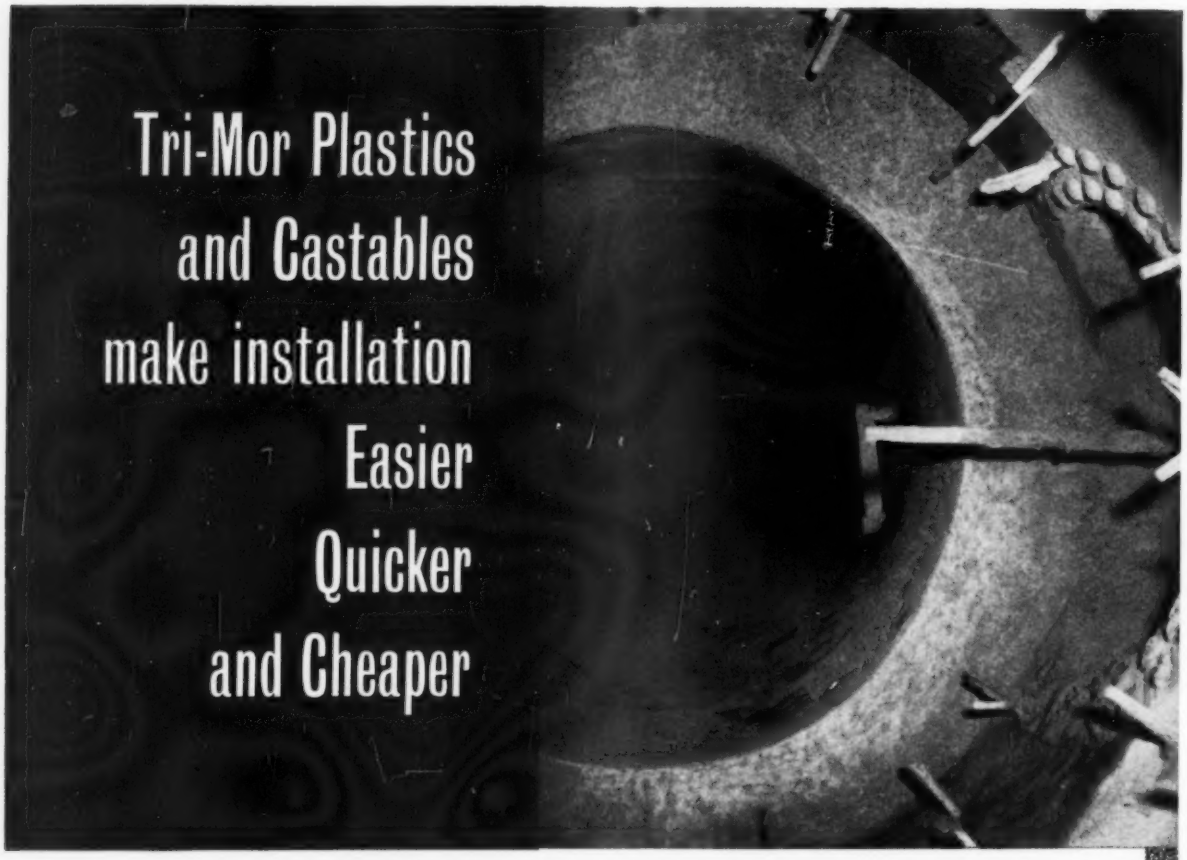
CONSETT IRON COMPANY, LIMITED
CONSETT · COUNTY DURHAM · ENGLAND

Telephone: Consett 341 (12 lines)

Telegrams: STEEL PHONE, Consett

Tri-Mor Plastics and Castables make installation Easier Quicker and Cheaper



Bustle main of Queen Victoria Blast Furnace showing 'gunned' lining in Tri-Mor Dense 'Guncrete'. (Inside diameter of shell 5 feet. Thickness of 'Guncrete' lining 9 inches).
Photograph by courtesy of the Appleby-Frodingham Steel Co. (Branch of the United Steel Companies Ltd.).

TRI-MOR GRADES

TRI-MOR *Standard Castable*

A medium texture refractory having negligible shrinkage up to 1,350°C. Suitable for casting special shapes or for monolithic structures. Limiting service temperature 1,350°C.

TRI-MOR *High Strength Castable*

A similar refractory to Tri-Mor Standard Castable, but specially developed to have very high mechanical strength over the lower temperature range. Maximum service temperature 1,250°C.

TRI-MOR *High Temperature Castable*

Suitable for face temperatures up to 1,600°C; has an extremely high resistance to thermal shock; used for cast in situ monolithic structures and for pre-cast refractory shapes; can be applied with a cement gun.

TRI-MOR *High Temperature Mouldable*

A plastic refractory for use up to 1,650°C: low shrinkage and a high resistance to spalling. Supplied mixed to the correct consistency for installation.

TRI-MOR *Dense "Guncrete"*

A hydraulic setting refractory with a maximum service temperature of 1,300°C. It has a high resistance to abrasion. Designed for application by cement gun, but can be trowelled.

TRI-MOR *Insulating Castable*

An insulating castable for maximum service temperatures of 1,200°C; low thermal conductivity is its main feature.

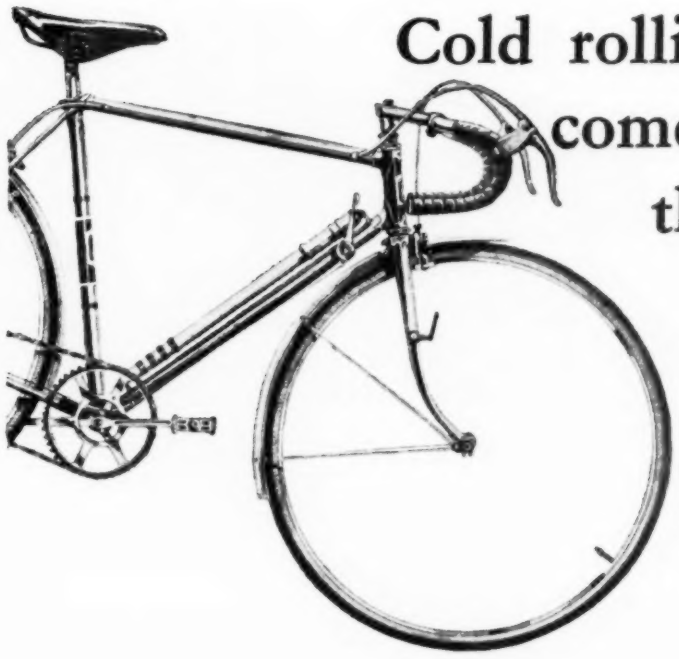
TRI-MOR *Insulating "Guncrete"*

Similar to Tri-Mor Insulating Castable but for application by cement gun.

Full details of each grade are available on request.

MORGAN Refractories Ltd

For further information write to: MORGAN REFRACTORIES LTD
NESTON, WIRRAL, CHESHIRE. TEL: NESTON 1406 NE 143



Cold rolling comes into this picture

You'd be surprised how many everyday things are made from metals which have been cold rolled on Doncasters rolls. In a cycle, for instance, there are probably the wheel rims, the chain wheel and chain parts, pedals, brakes and other fittings—all incorporating cold rolled products. Doncasters Hardened Steel Rolls are chosen by many of the important cold rollers of ferrous and non-ferrous metals for their consistant high quality.

DONCASTERS ◇
1778 D D

HARDENED STEEL ROLLS

The production of 'D-Diamond-D' Hardened Steel Rolls demands the very best steel to begin with, and throughout the forging, heat-treatment, grinding, polishing and inspection the most rigorous chemical, physical and mechanical tests are imposed; the finished product represents a supreme metallurgical achievement.

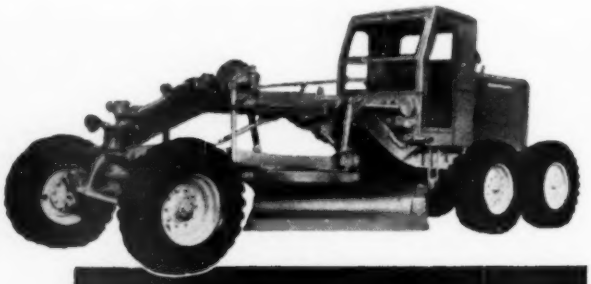
DANIEL DONCASTER & SONS LIMITED · SHEFFIELD
FORGINGS · DROP FORGINGS · HARDENED STEEL ROLLS · HEAT TREATMENT

R 25

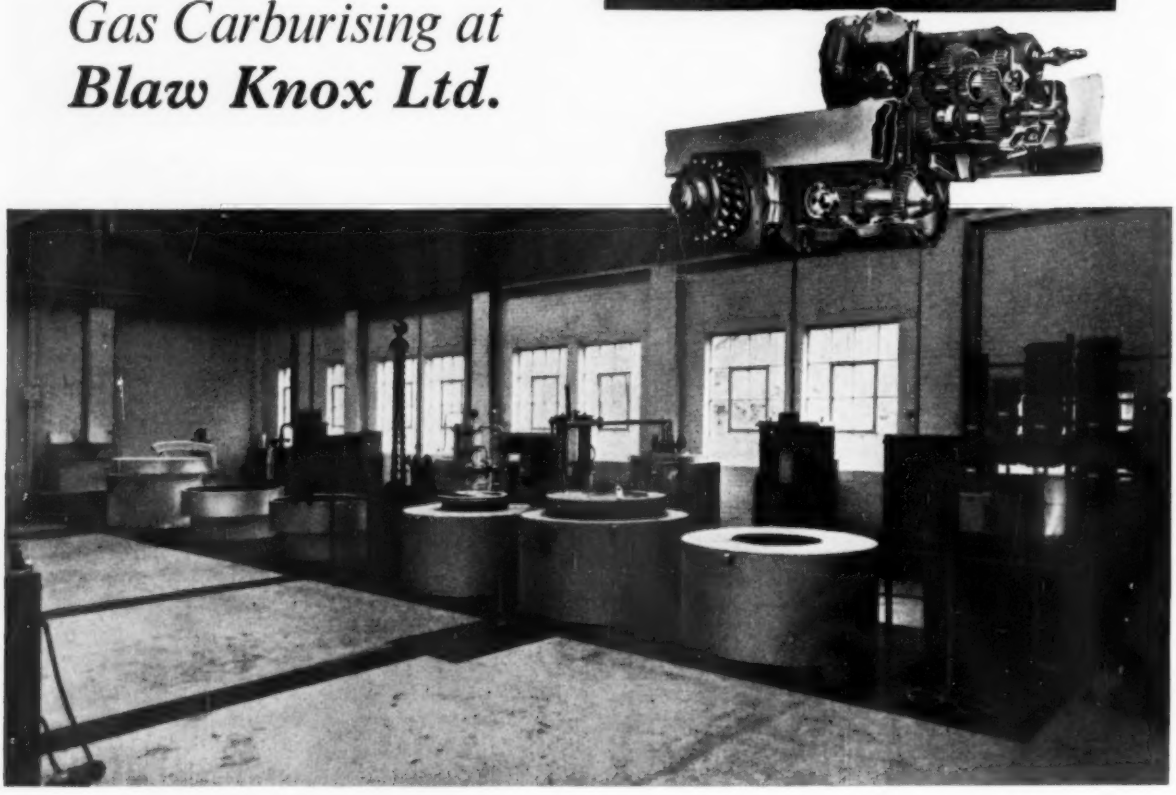
They rely on

WILD BARFIELD

Gas Carburising at
Blaw Knox Ltd.



Gears and main driving shafts for the BK-"Super-12" Motor Grader have to stand up to exceptionally tough working conditions. Wild-Barfield gas carburising equipment is used in their manufacture.



Wild-Barfield "P.T.G." Gas Carburising installation at Blaw Knox Ltd.

Precise control of depth and type of case is afforded by both Wild-Barfield gas carburising processes—the "P.T.G." and "Carbodrip" drip feed. By these methods carburising proceeds at almost the maximum theoretical rate. We will be glad to send you full details on request.

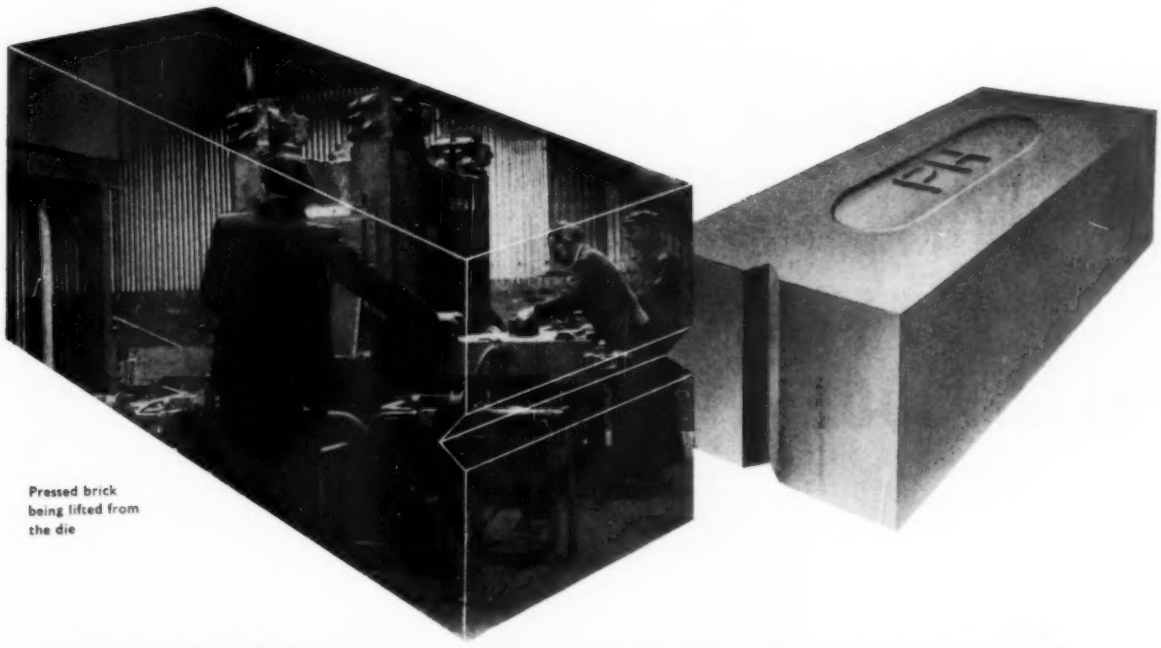
ELECTRIC WILD BARFIELD FURNACES

FOR *ALL* HEAT-TREATMENT PURPOSES

WILD-BARFIELD ELECTRIC FURNACES LIMITED

ELECFURN WORKS, OTTERSPOOL WAY, WATFORD BY-PASS, WATFORD, HERTS. Telephone: Watford **26091** (8 lines)

WB 51



Pressed brick being lifted from the die

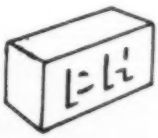
PRESSING PROBLEM SOLVED

Pickford Holland install the latest hydraulic presses for standard and special shapes

Refractory bricks today must be absolutely accurate in size and shape. These qualities, combined with unerring consistency in texture and performance are achieved by Pickford Holland through the medium of the most modern plant and equipment.

In Pickford Holland works, the very latest crushing, grinding and mixing plant, powerful hydraulic presses and continuous tunnel firing kilns have been and are being installed. Rigid control of the various processes is strictly observed, and the finished bricks are carefully inspected and tested before being despatched to the consumer.

More and more Pickford Holland refractory bricks are being supplied to steel and other industries throughout the world and the demand still grows. This surely points to the success of this policy of plant modernisation and is a tribute to the lasting service that these bricks give.



PICKFORD HOLLAND *Refractory Bricks*

Consistent in Size, Shape, Texture and Performance

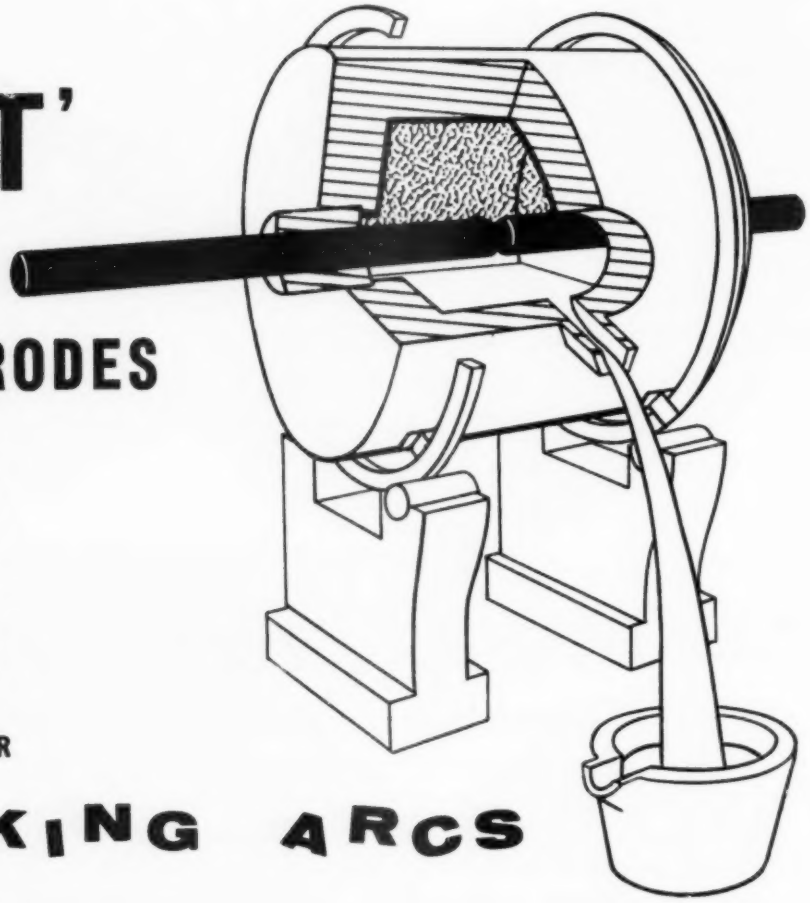
PICKFORD, HOLLAND & CO. LTD., 381 FULWOOD ROAD, SHEFFIELD 10, TELEPHONE 33921.

'DT'

ELECTRODES

FOR

ROCKING ARCS



'ACHESON' Graphite Electrodes machined to 'DT' specifications are specially suited for indirect arc furnaces. These Electrodes are manufactured to a consistently high quality by a carefully controlled process. This assures excellent performance.

There is a size of 'DT' *Acheson* Electrode for every furnace.

ACHESON GRAPHITE

The term ACHESON is a registered trade mark

BRITISH ACHESON ELECTRODES LIMITED WINCOBANK, SHEFFIELD. Telephone: Rotherham 4836

Wild-Barfield Progressive Hardening Machine at MORRIS Engines Limited

Hardening of valve rocker shafts at Morris Engines Ltd., is carried out on Wild-Barfield Progressive Hardening Machines. (Note the hardness pattern on the rocker arm that is being removed.) This is a typical application of this proved unit of the well-known Wild-Barfield range of induction heating equipment.

Some technical facts.

This fixture caters for lengths from 1" to 30", or longer in special cases, diameters from ½" upwards depending on the size of Wild-Barfield A.H.F. Generator used. A simple cam change enables any desired hardness pattern to be obtained giving hard and soft zones as required. The construction follows machine tool practice and incorporates traverse speed control which, together with power control on the generator, makes the equipment extremely versatile.

WILD-BARFIELD ELECTRIC FURNACES LIMITED
(High Frequency Division)

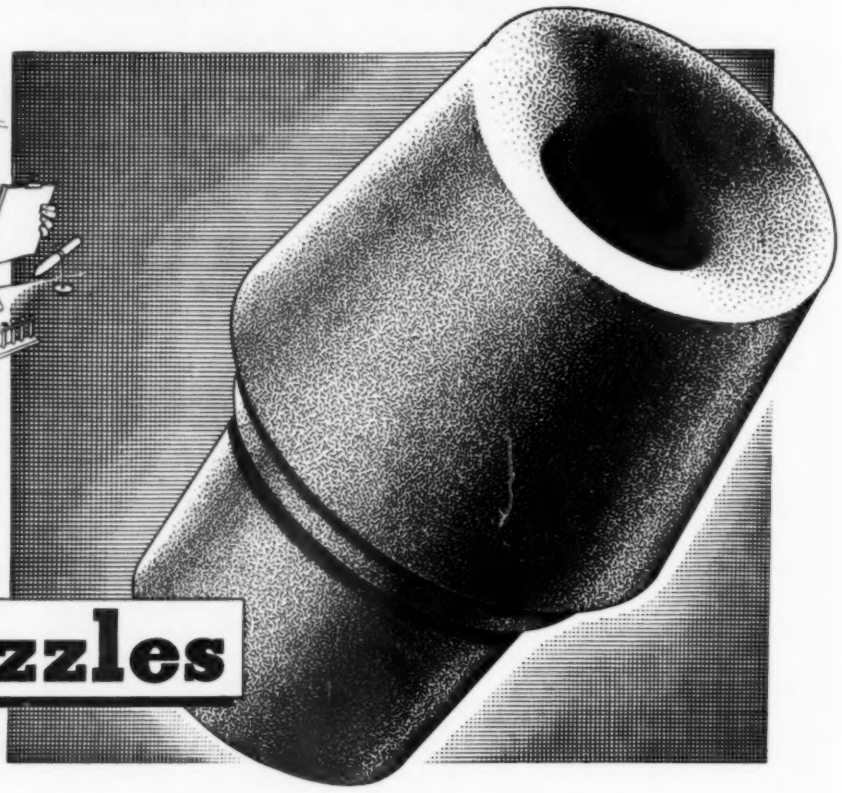
ELECFURN WORKS,
OTTERSPOOL WAY,
WATFORD BY-PASS,
WATFORD, HERTS.
Tel: Watford **26091** (8 lines)

WILD BARFIELD A.H.F.

INDUCTION HEATING SPEEDS PRODUCTION

WB 75

SPECIAL JOBS REQUIRE SPECIAL NOZZLES



Nozzles

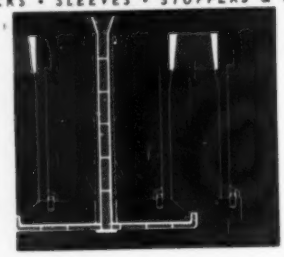
To meet today's stringent specification, steelmakers sometimes demand special nozzles.

Marshall's "CT" Nozzle Insert is now accepted and widely recommended for Sulphur, Manganese and Ledloy Steels.

Marshalls' also supply the more traditional Magnesite Inserts and Thimbles as well as simple and composite nozzles in different qualities of fireclay to suit various needs.

Let Marshall's technical advisory service help you to get the right nozzle for *your* requirements.

LADLE BRICKS • SLEEVES • STOPPERS & NOZZLES • TRUMPETS & PIPES • CENTRE BRICKS & RUNNERS • MOULD HEAD BRICKS



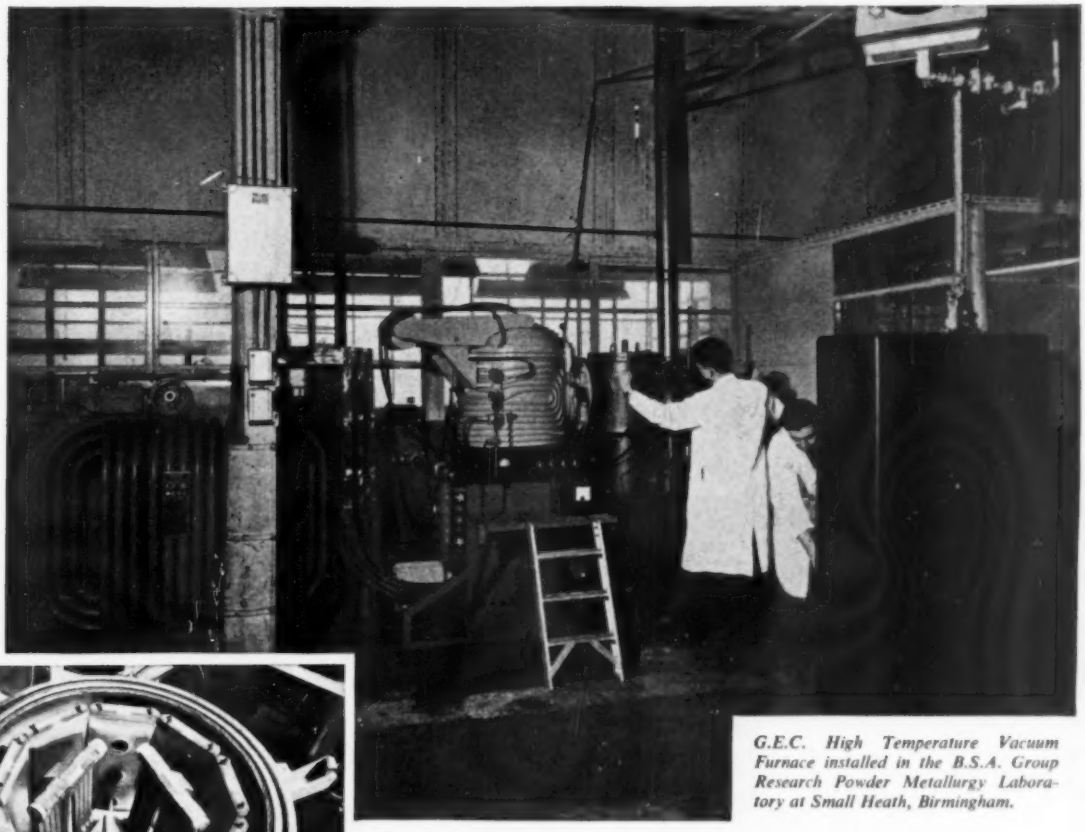
MARSHALL

REFRACTORIES

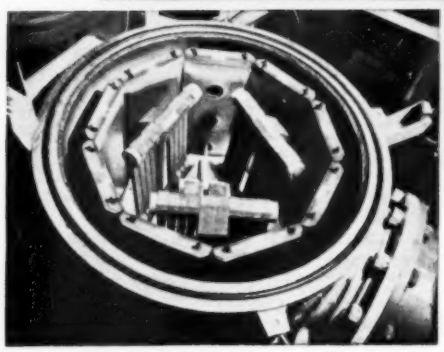
THOMAS MARSHALL & CO (LOXLEY) LTD · LOXLEY · SHEFFIELD

One of the MARSHALL REFACTORIES GROUP of Companies

B.S.A. use a G.E.C. High Temperature Vacuum Furnace...



G.E.C. High Temperature Vacuum Furnace installed in the B.S.A. Group Research Powder Metallurgy Laboratory at Small Heath, Birmingham.



The furnace element assembly and side radiation screens.

for sintering materials for use at high temperatures

G.E.C. vacuum furnaces meet the need for high temperatures for such applications as sintering and degassing, brazing with nickel chromium alloys, heat treating titanium, tantalum and zirconium.

They provide an operating vacuum between 10^{-4} and 10^{-5} mm. mercury. Temperatures up to 2000°C. have been achieved.

Write for further details.

for efficient process heating use

G.E.C.

FURNACES • HIGH FREQUENCY • INFRA-RED

69

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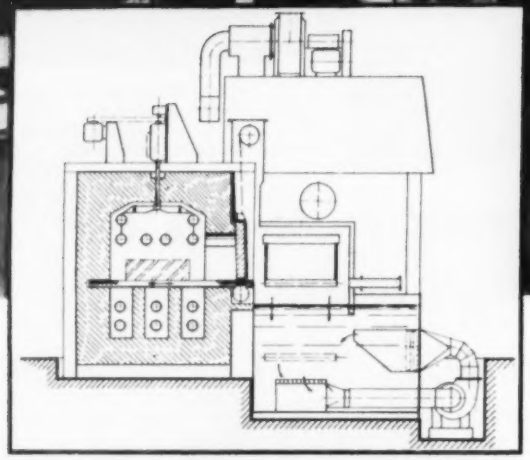

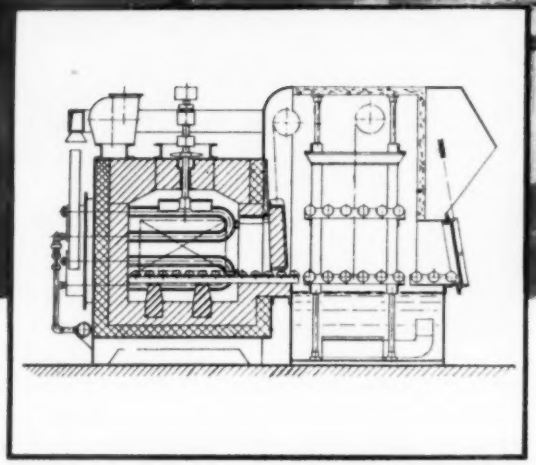

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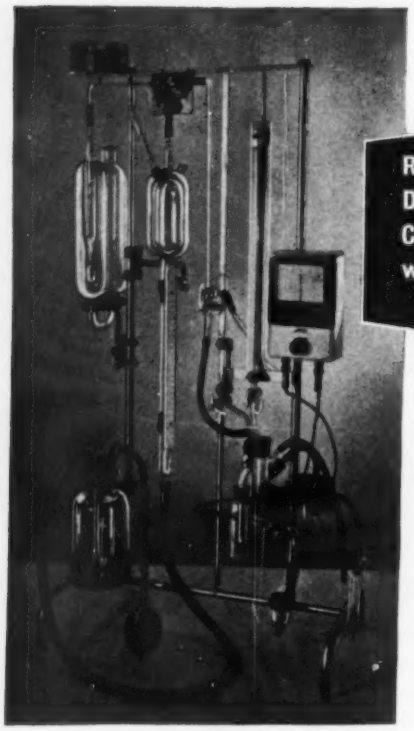

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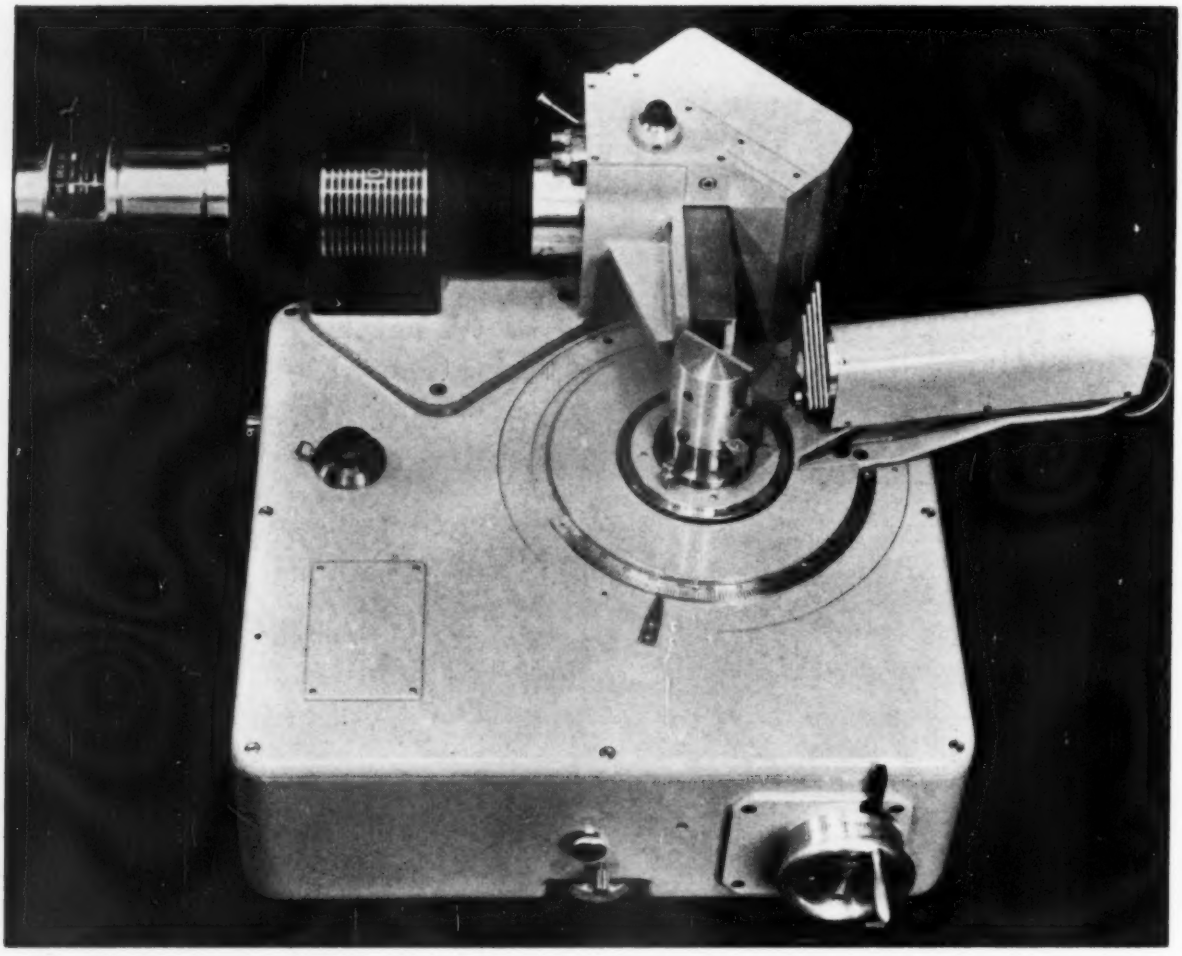

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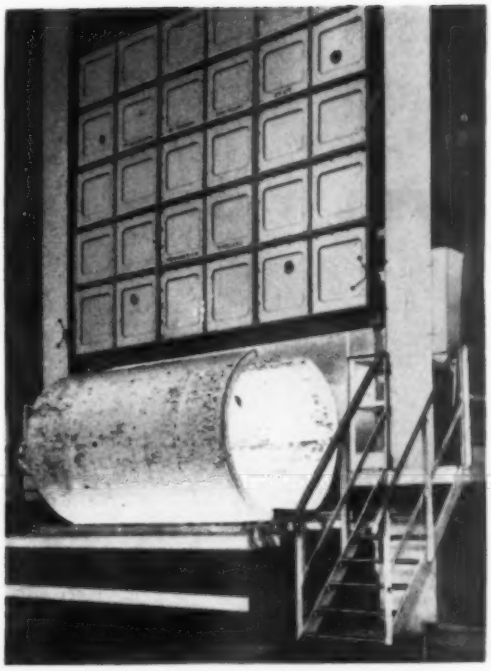

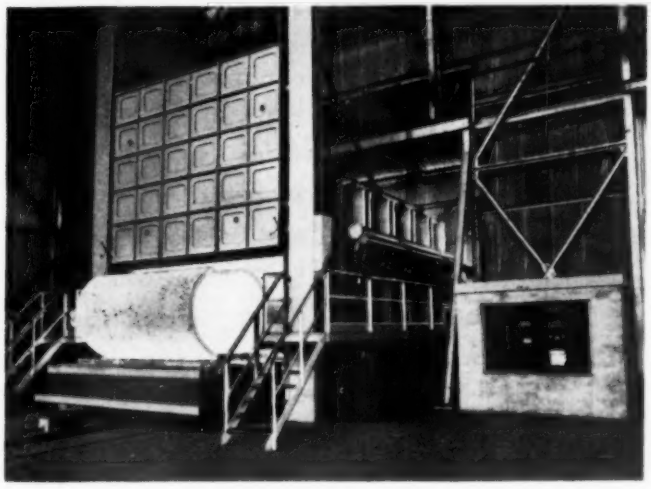

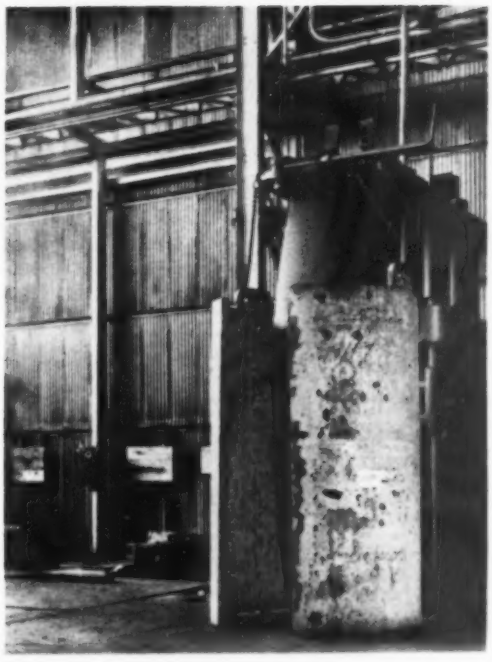

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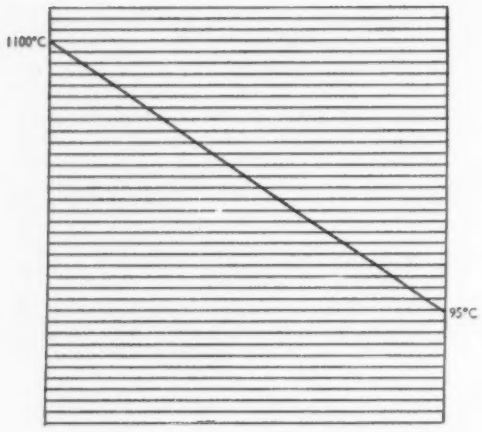

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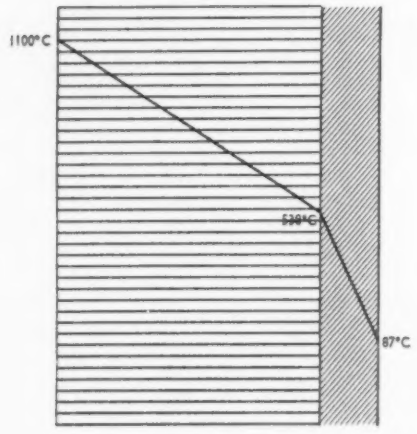

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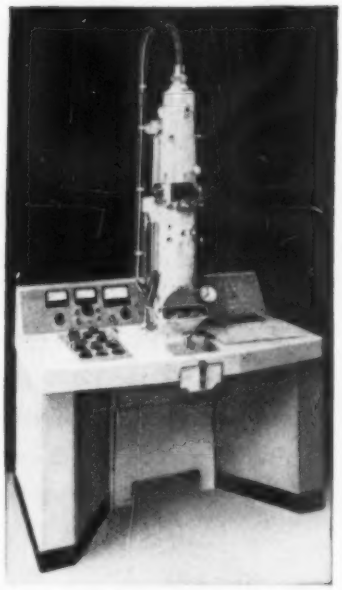

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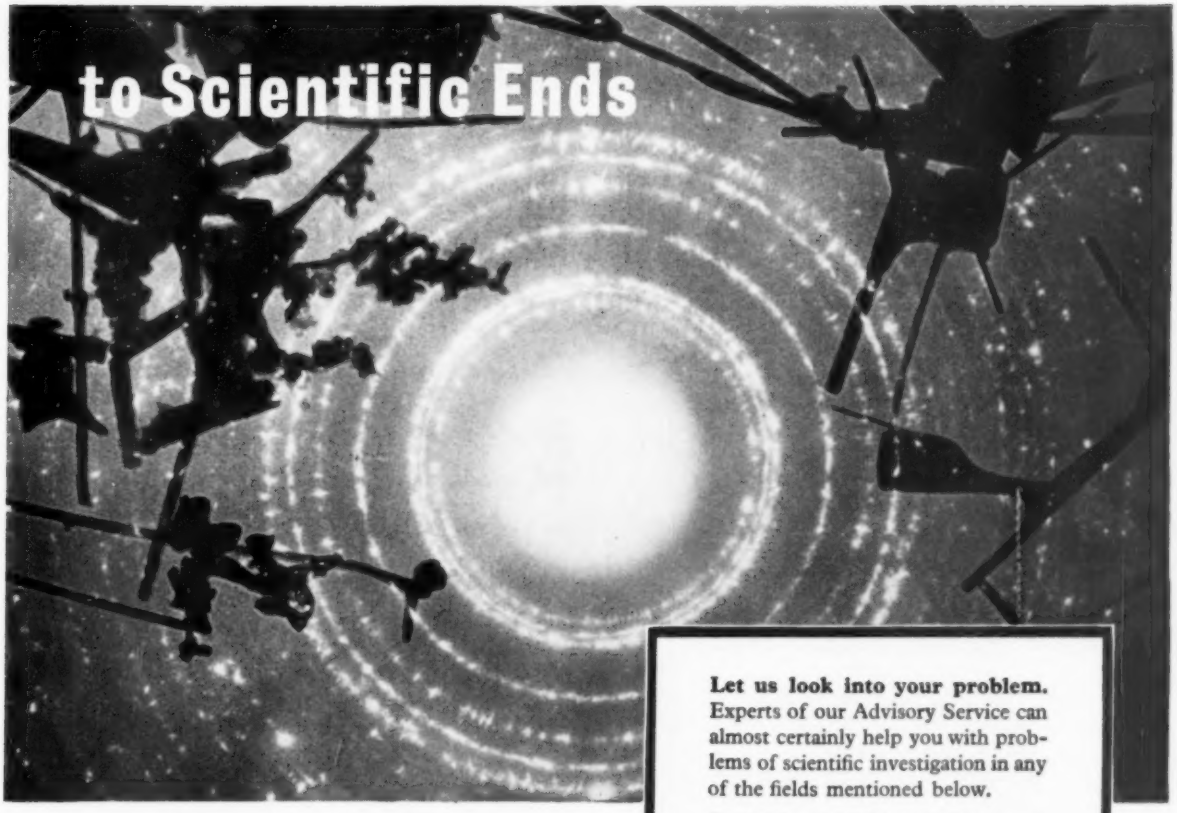

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THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

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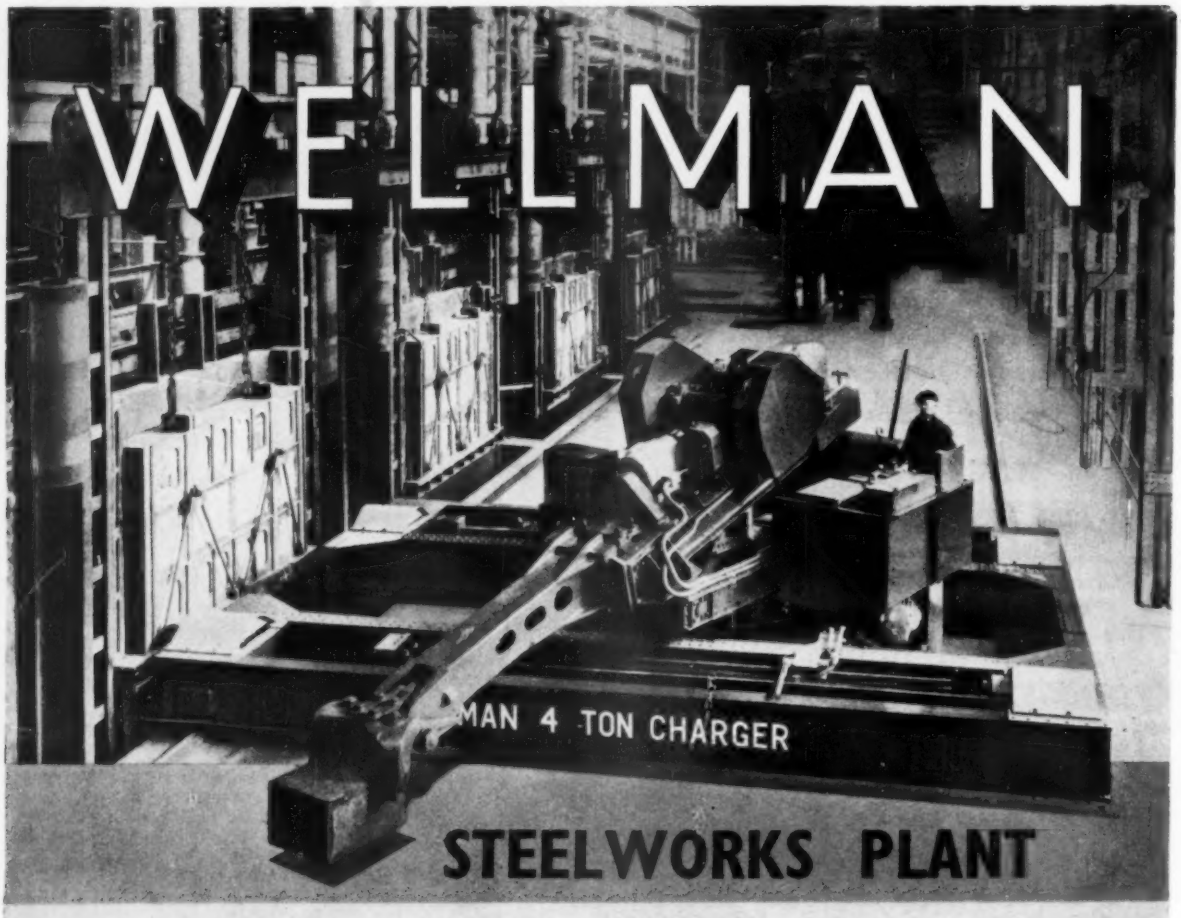

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FEBRUARY, 1959 Vol. LIX. No. 352

Cobalt

COMPARED with those for the more widely used engineering metals such as steel, aluminium, copper, etc., the world production figures for cobalt seem very small. Nevertheless they have increased almost fourfold in the last twenty years, and in 1957 had reached 14,600 metric tons. It is a far cry from the time when the ancient Egyptians—some four thousand years ago—used a cobalt-base colouring agent in making blue glass, to the present day when cobalt finds such widespread application in a host of metallic materials.

This could scarcely be described as a period of continuous development, for the secret of the manufacture of the blue glass referred to above seems to have been lost until the sixteenth century. Around 1520, in Saxony, a blue pigment was produced from complex arsenical silver-cobalt-nickel-bismuth ores, which gave on smelting a speiss which was metallic in appearance, but brittle and of no practical use. The miners of the day were unable to refine this speiss and saw in it the working of "Kobold," the German word for goblin; hence the name of one of the metals included in the speiss. At a later date, Brandt separated the metal whose impure oxide had been used for so long to colour glass, and in 1790 Bergman proved cobalt to be a chemical element.

In 1880, cobalt-bearing deposits were found in New Caledonia, and during the next quarter of a century some 100,000 tons of 3% cobalt ore were exported from this source, and for the same period the world production of oxide was 250–300 tons per annum. The discovery of the large silver-nickel-cobalt ore deposits in Canada in 1905, however, led to the closing of the workings in New Caledonia. At that time there were no known applications for metallic cobalt, but a few years later it was shown that cobalt additions improved considerably the properties of high speed steels, and from that time onwards the use of cobalt as a metal, rather than in the form of a compound, has increased greatly. Cobalt compounds are of course, used extensively in the production of ceramics, enamels, glass, paints, inks, etc., and in the petroleum and chemical industries cobalt in various forms serves as a catalyst. One of the most interesting non-metallurgical applications of cobalt results from its beneficial action on the health of animals suffering from deficiency diseases.

Returning to the metallurgical applications of cobalt, these now include heat-resisting alloys, magnet alloys, hardfacing alloys, cermets, high speed tool steels, wear-resisting alloys, and miscellaneous alloys. Today the principal uses, as far as tonnage is concerned, are to be found in the production of heat-resisting alloys and magnet alloys. The United States figures for 1957 show that the combined demand for these purposes amounted to more than half the total U.S. consumption of 4,200 metric tons. Individually they accounted for about ten times as much as did cermets, wear-resisting alloys, or high speed tool steels. The figure for hard facing alloys was about 230 tons, and for miscellaneous alloys 160 tons.

The use of cobalt-containing heat-resisting alloys has increased rapidly with the development of gas turbines and jet engines, and the United States consumption for this purpose showed an abnormal rise in the early 1950's as a result of the Korean War. Because of the military aviation requirements at that time, and the consequent restrictions on its use for other purposes, cobalt came to be regarded as scarce, of uncertain supply, and reserved only for strategic applications. This is no longer the case, and present production capacity can cope with all civilian as well as military needs.

By far the biggest single producer of cobalt is the Belgian Congo, which has an output four times as big as that of Canada: the next largest other producers include the U.S.A., Rhodesia, Germany (from Finnish pyrites and scrap), and Morocco, together with, on a smaller scale, Australia, Mexico, Japan, etc. The known cobalt reserves are sufficient to ensure supply at the present rate of consumption for at least eighty years, and the opening of new mines and refineries together with future expansion of existing plants will lead to a 50% increase in annual production capacity within a few years.

In order to develop the uses of cobalt and to assist consumers and research workers interested in the applications of the metal and its alloys and compounds, the world's leading cobalt producers have set up in Brussels, with a branch office at the Battelle Memorial Institute, Columbus, Ohio, the Centre d'Information du Cobalt, S.A.: this is the executive organisation of the Cobalt Development Institute founded in 1957. The first issue of a new quarterly publication *Cobalt* features a general survey of the various uses of cobalt and an article on heat resisting alloys. Similar articles on other uses will appear in future issues, thus furthering the Centre's aim of assisting consumers. In addition scientists conducting investigations for the Centre will contribute papers based on the results of their work.

In order to find new applications for cobalt and to increase its known uses, the Centre has undertaken an extensive research programme, which is being carried out by specialised laboratories in Europe and America. It is felt that a deeper knowledge of the properties of cobalt-base materials could lead to a much wider use of the metal, as although it has many applications, the lack of theoretical data concerning its behaviour often hinders the development of further uses. Some of the studies—relating to creep behaviour, magnetic properties, catalysis, phase diagrams, structural phenomena in alloys, etc.—are of a purely scientific nature, and are not expected to lead to immediate practical results. Others are intended to develop new materials for specific uses. These include studies on cermets, heat-resisting alloys, electroplating or electrolysis deposition of cobalt alloys, creep-resisting steels, materials for airframe structures, plastics, etc.

Meeting Diary

14th February

Institute of British Foundrymen, Scottish Branch. "Safety in the Foundry", by H. P. MILLER. Royal College of Science and Technology, Glasgow, C.1. 3 p.m.

16th February

Institution of Mechanical Engineers, Scottish Centre. "Fatigue Testing of Vehicle Components", by T. C. F. SCOTT. 39, Elmbank Crescent, Glasgow, C.2. 7.30 p.m.

Sheffield Society of Engineers and Metallurgists. "Automatic Press Forging", by J. G. WISTREICH and J. D. STRINGER. The University Building, St. George's Square, Sheffield. 7.30 p.m.

17th February

Sheffield Metallurgical Association. "Why are Steel-making Reactions so Slow?" by DR. R. G. WARD, B.I.S.R.A., Hoyle Street, Sheffield. 7 p.m.

18th February

Institute of Welding, West of Scotland Branch. "The Computer Controlled Flame Profiling Machine", by C. STEVENSON. 39, Elmbank Crescent, Glasgow, C.2. 7 p.m.

Manchester Metallurgical Society. "High Temperature Alloys", by D. R. WOOD. Manchester Room, Central Library, Manchester. 6.30 p.m.

19th February

Institute of Metals, Birmingham Local Section. "Materials for Reactors", by DR. B. C. WOODFINE. College of Technology, Gosta Green, Birmingham. 6.30 p.m.

Institute of Fuel, North-Western Section. "Liquid Fuels and Appliances for Domestic Heating", by S. S. WHITEHEAD. Blossoms Hotel, Chester. 7.30 p.m.

North-East Metallurgical Society. "Metallurgical Education", by PROF. G. V. RAYNOR. Cleveland Scientific and Technical Institution, Middlesbrough. 7.15 p.m.

20th February

Institution of Structural Engineers, Scottish Branch. "Modern Trends in the Design of Steel Bridges and Structures", by W. R. COX. Joint Meeting with the Institution of Civil Engineers. 39, Elmbank Crescent, Glasgow, C.2. 7 p.m.

24th February

Institution of Engineers and Shipbuilders in Scotland. "The Stork Marine Diesel Engine—Construction Experience, Development", by IR. A. HOOTSEN and E. A. VAN DER MOLEN. 39, Elmbank Crescent, Glasgow, C.2. 6.30 p.m.

Institute of Fuel, Scottish Section. "Present Trends in Research on Coking Properties of Coals", by HELEN MCKELLAR. Royal College of Science and Technology, Glasgow. 7 p.m.

Society for Analytical Chemistry. "Analysis of Intact Samples": (1) "The Use of Beta and Gamma Absorption Methods in the Analysis of Intact Samples", by J. F. CAMERON; (2) "The Use of Radioactive Isotopes in Simple X-Ray Fluorescent Analysis", by C. E. MELLISH; (3) "Analysis by Nuclear Magnetic Resonance Techniques", by D. J. FERRETT. Meeting Room of the Chemical Society, Burlington House, Piccadilly, London, W.1. 6.30 p.m.

25th February

Sheffield Society of Engineers and Metallurgists, Joint Meeting with the Yorkshire Branch of Institution of Mechanical Engineers. "The Mechanical Marshalling of Railway Wagons in Works Sidings", by G. W. GROSSMITH, M.C. The University Building, St. George's Square, Sheffield. 6.30 p.m.

26th February

Institute of Metals, Sheffield Local Section. Symposium on Corrosion. Three or four short papers, followed by a general discussion. Engineering Lecture Theatre, The University, St. George's Square, Sheffield, 1. 2 p.m. to 5.30 p.m.

Southampton Metallurgical Society. "Gases in Metals", by DR. C. E. RANSLEY. Small Physics Lecture Theatre, The University, Southampton. 7.15 p.m.

3rd March

Institute of Metals, Oxford Local Section. "Metallurgical Applications of the Electron Microscope", by DR. J. NUTTING. Cadena Cafe, Cornmarket Street, Oxford. 7 p.m.

Institute of Metals, South Wales Local Section. "Effects of Vacancies and Other Point Defects in Metals", by PROF. A. H. COTTRELL, F.R.S. Department of Metallurgy, University College, Singleton Park, Swansea. 6.30 p.m.

Sheffield Metallurgical Association. "The Competitive Position of the British Steel Industry", by E. T. SARA. B.I.S.R.A., Hoyle Street, Sheffield. 7 p.m.

4th March

Manchester Metallurgical Society. "The Behaviour of Steels During Hot Working, with Particular Reference to Hot Extrusion Processes", by P. SUKOLSKI. Manchester Room, Central Library, Manchester. 6.30 p.m.

Society of Chemical Industry, Corrosion Group. "The Diagnosis of the Causes of Corrosion Failures":—(1) "A Systematic Scheme for Examining Corroded Metal Specimens", by J. B. COTTON; (2) "The Examination of the Corrosion Products of Aluminium and its Alloys", by R. A. HINE; (3) "Investigation of Corrosion Failures of Iron and Steel", by E. E. WHITE and K. A. CHANDLER. Society of Chemical Industry, 14, Belgrave Square, London, S.W.1. 6.30 p.m.

5th March

East Midlands Metallurgical Society. "Plastic Coated Steel Sheet", by F. H. SMITH and W. E. MARTIN. College of Art, Green Lane, Derby. 7.30 p.m.

Institute of Metals, London Local Section, Joint Meeting with the Institute of Welding. "High Temperature Brazing", by A. CIBULA. 17, Belgrave Square, London, S.W.1. 6.30 p.m.

Leeds Metallurgical Society. "Metallurgical Applications of High-Resolution Microscopy", by DR. J. NUTTING. Lecture Room C, Chemistry Wing, The University, Leeds, 2. 7.15 p.m.

9th March

North East Metallurgical Society. "Development of the Tungsten Filament Lamp", by DR. B. P. DUDDING. Cleveland Scientific and Technical Institution, Middlesbrough. 7.15 p.m.

10th March

Sheffield Metallurgical Association. "Impact Transition Temperatures", by DR. B. CINA. B.I.S.R.A., Hoyle Street, Sheffield. 7 p.m.

12th March

Liverpool Metallurgical Society. "The Rare Metals Used in Atomic Energy Applications", by L. R. WILLIAMS. Library of the Dept. of Metallurgy of the University of Liverpool, 146, Brownlow Hill, Liverpool, 3. 7 p.m.

Powder Metallurgy Joint Group of the Iron and Steel Institute and the Institute of Metals. Informal Discussion (all day) on "Theoretical Aspects of Sintering." Church House, Great Smith Street, London, S.W.1.

13th March

West of Scotland Iron and Steel Institute. Joint Meeting with the Iron and Steel Institute, Engineers Group. "The Installation and Commissioning of an 80-ton Electric Arc Furnace", by P. M. THOMAS, D.S.O., and A. MACNAUGHTON. 39, Elmbank Crescent, Glasgow. 6.45 p.m.

14th March

Institute of British Foundrymen, Scottish Branch. "Production of S.G. and Alloy Irons in Steelwork Practice", by G. GRIGG. Royal College of Science and Technology, Glasgow, C.1. 3 p.m.

1959 Corrosion Exhibition

PROTECTING hundreds of millions of pounds worth of Armed Forces' equipment against corrosion damage is a major task of Ministry of Supply scientists. It is appropriate, therefore, that Britain's 1959 Corrosion Exhibition should be opened on Monday, April 27th by the Chief Scientist of the Ministry of Supply, Sir Owen Wansbrough-Jones, K.B.E., C.B. Over 70 firms are showing at the Exhibition which will be open for four days, April 27th to 30th, at the Royal Horticultural Society's New Hall, Westminster. Tickets are available from the organisers, *Corrosion Technology*, Leonard Hill House, Eden Street, London, N.W.1.

Binary and Ternary Alloys of Tin with the Elements of Groups IIB, IIIB and VB of the Periodic Table*

By H. W. Rayson, C. W. Goulding and G. V. Raynor

Department of Physical Metallurgy, University of Birmingham.

To examine the effect of third metals on the simple hexagonal tin-rich intermediate phases of the β_{Sn-Cd} type, tin-rich alloys of the systems tin-cadmium-zinc, tin-cadmium-thallium, tin-cadmium-bismuth and tin-indium-antimony have been examined by metallographic, X-ray, and electrical resistance methods. Experiments on the binary systems tin-cadmium, tin-zinc, tin-thallium and tin-indium were also carried out to clarify discrepancies in the literature. β_{Sn-Cd} dissolves comparatively little zinc or thallium, for which the closest distances of approach in the crystals of the elements differ appreciably from that for tin: approximately 0·7 at.-% zinc and 1·5 at.-% thallium dissolve at temperatures of 156° and 132° C., respectively. Although bismuth does not form a hexagonal tin-rich phase with tin, the β_{Sn-Cd} phase dissolves appreciable quantities of bismuth; at the same time the eutectoid temperature corresponding to the decomposition of β_{Sn-Cd} is lowered from 132·5° C. to a minimum of 86° C. At 125° C., the ternary phase based on β_{Sn-Cd} contains a maximum of about 9 at.-% bismuth, the solution taking place so as to maintain an electron : atom ratio close to that characteristic of β_{Sn-Cd} itself. Analysis of results in the literature for the tin-cadmium-antimony system shows that when antimony dissolves in β_{Sn-Cd}, a constant electron : atom ratio is again maintained. The results are briefly discussed and confirm the importance of atomic size and valency effects in the formation of the tin-rich hexagonal phases.

AMONG binary tin-rich alloys, there are relatively few cases in which tin dissolves appreciable amounts of other elements in the solid state. For this reason, comparatively little accurate information is available upon which to attempt to develop a theory of the alloying behaviour of tin. A striking characteristic of the physical metallurgy of tin, however, is the formation of tin-rich intermediate phases with cadmium, indium and mercury. The tin-cadmium β phase is stable only at temperatures above about 133° C., and decomposes eutectoidally at about 5 at.-% cadmium into the tin-rich and cadmium-rich solid solutions.[1] In the tin-indium alloys,[2] a phase usually denoted γ, existing over a range of compositions, is stable from the solidus to room temperature. The tin-mercury system, according to Gayler,[3] contains two tin-rich intermediate phases, one (β) stable only at high temperatures, and the other (γ) stable from the solidus to room temperature; both phases occur at closely similar solute concentrations, and it is doubtful, in view of recent work, whether they should be regarded as distinct. In considering the alloying characteristics of tin, it appeared to be profitable to study the formation of these tin-rich phases in greater detail; it has now been shown[4] that the phases mentioned above, (β_{Sn-Cd}, γ_{Sn-In}, β_{Sn-Hg} and γ_{Sn-Hg}), all have simple hexagonal structures, with axial ratios which increase as the electron : atom ratio of the phase decreases, assuming that the four metals exert their group valencies. In further examination of the problem, it was of interest to examine the behaviour of these phases, of which β_{Sn-Cd} may be regarded as typical, in chosen ternary systems, since this procedure afforded means of varying atomic size relationships without affecting electronic considerations (system tin-cadmium-zinc), or of changing the electronic conditions without affecting atomic size relationships appreciably (system tin-cadmium-thallium). Since bismuth is soluble to an appreciable extent in tin, the system tin-cadmium-bismuth was included to allow examination of the effect of bismuth on β_{Sn-Cd}; also, for comparison of the behaviour of β_{Sn-Cd} and γ_{Sn-In}, the system tin-indium-antimony was studied.

* Received May 14th, 1957

In preparation for the work on the ternary systems, certain aspects of the alloys of tin with cadmium, zinc, thallium and indium were re-examined, and are reported in the present paper, together with the ternary results.

Experimental Methods

In the course of the research, the main methods employed were metallography, X-ray powder diffraction, and the measurement of electrical resistances of alloys as a function of both composition and temperature. To a more limited extent, dilatometric and hot-stage microscopic techniques were used.

The materials used were as follows:

(*i*) Chempur tin, 99·999% pure, kindly presented by the Tin Research Institute.

(*ii*) Cadmium, of purity exceeding 99·99%, kindly presented by the National Smelting Corporation, of Avonmouth.

(*iii*) Zinc, 99·995% pure and containing as the major impurity 0·002% copper, also presented by the National Smelting Corporation.

(*iv*) Spectrographically standardised indium and thallium, obtained from Messrs. Johnson, Matthey & Co., Ltd.

(*v*) Bismuth, of purity exceeding 99·98%, obtained from the Goodlass Lead and Antimony Company.

Alloys were prepared from the carefully weighed components in quantities varying from 5 to 20 g., according to the availability of the pure metals. Several melting techniques were employed; excellent results were obtained by melting in preheated silica crucibles at 250° C. under a layer of glycerol (b.p. 290° C.) and casting, after stirring, into chill copper moulds. Alternatively, melting was carried out in hard glass tubes through which a current of purified argon was passed, or, where higher temperatures of melting proved advisable, as in the system tin-cadmium-antimony, in sealed evacuated silica tubes. In the latter case, the well-shaken tube containing the melt was placed in a cylindrical hole in a

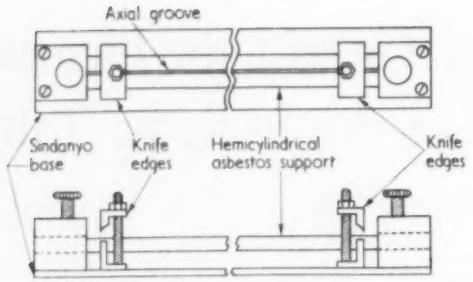

Fig. 1. Specimen holder for resistance measurements at constant temperature.

cold copper block to secure rapid solidification before the tube and its contents were quenched into cold water.

Wherever possible, alloy specimens were severely deformed in the as-cast state before annealing. Annealing was carried out, with specimens sealed in evacuated glass tubes, either in tubular resistance furnaces or oilbaths; in certain cases, where it was known that alloys would remain completely solid at the temperature involved, and where a specially rapid quench was required, the specimens were annealed in direct contact with the oil of the bath, being supported in wire cages. In general, the temperature of annealing was automatically controlled to within $\pm 0{\cdot}1^\circ$ C. The appropriate times of annealing were decided after tests for equilibrium had been carried out by metallographic and electrical resistance methods, and are referred to in connection with individual alloy systems.

Metallographic preparation of the tin-rich alloys, which were in most cases soft, presented difficulties, but good results could be obtained by conventional techniques. Owing to the structural instability of certain of the alloys, development of heat in the surface was scrupulously avoided. The final polish was given with Brasso on Selvyt cloth; for very soft alloys it was difficult to avoid embedding fine emery particles in the surface, and in such cases it was advantageous to polish, and to etch in alcoholic ferric chloride solution, alternately. As the work developed, it was found that excellent surfaces were obtained by electrolytic polishing in 10% aqueous hydrochloric acid, or, preferably, in a mixture of two parts of perchloric acid, one of glycerol and seven of ethanol by volume.* Alloys containing thallium or bismuth, however, could not be polished electrolytically.

Numerous etching reagents were investigated in an effort to obtain clear metallographic results, but only a very limited number proved reliable; these are referred to in connection with individual alloy systems. Owing to the difficulties introduced by the decomposition on quenching of the $\beta_{Sn\text{-}Cd}$ phase, and the ternary phases based on it, a number of confirmatory experiments were carried out using hot-stage microscopy, and also by etching before quenching, while the specimens were at the annealing temperature in the furnace. Since no essentially new information was obtained by these methods, they are not described in detail.

The general difficulty encountered in metallographic experiments led to the construction of apparatus for the measurement of electrical resistance at elevated temperatures. The specimens were initially prepared as chill cast ingots, approximately 5 mm. in diameter. These were extruded under a pressure of 2,000 lb./sq. in. at a speed of 1 cm./sec. through a 1·5 mm. diameter hole; the extrusion temperature was 100° C., or, in the case of tin-cadmium binary alloys, 120° C. Resistance specimens 25 cm. long were cut from the central portions of the extruded wire, and the remainder used for micrographic examination and chemical analysis. Each specimen was annealed in a sealed Pyrex sheath of 2 mm. diameter, at the temperature at which subsequent resistance measurements were planned; the annealing time was decided by mounting trial wires in the resistance apparatus immediately after extrusion, and noting the time necessary for the attainment of a constant resistance value. After annealing, the wires were quenched into ice-water, and carefully examined for faults, such as uneven cross-sections or fine transverse cracks. Only fault-free specimens were used in the experiments, which were carried out in duplicate for each alloy.

The specimens were soft and required careful handling. For resistance experiments, they were supported in the special jig illustrated in Fig. 1; the brass knife edges between which the potential drop was measured were approximately 20 cm. apart. At the beginning of the experiment, current and potential connections were made at one end only. The holder was then placed in an insulated oil bath* which was controlled within $\pm 0{\cdot}1^\circ$ C. of a pre-determined temperature, and the remaining current and potential connections were made after the specimen had expanded and taken up the bath temperature. Current was supplied from a 6 volt accumulator, and the potential drop between the knife-edges was compared with that across a standard resistance (0·1 ohm) in series with the specimen, by means of a Cambridge Vernier Potentiometer capable of reading to 1×10^{-7} volt. The effects of possible thermal E.M.F's were minimised by the usual method of current reversal, the mean of the two readings being taken. In general, resistances were determined for currents of both 0·25 and 0·75 amp. and the values agreed well. In all cases, measurement was continued at intervals until a completely steady value was obtained, showing adequate recovery from any strains introduced by quenching and mounting.

After careful removal from the apparatus, the specimen length was measured at room temperature by determining the distance between knife edge traces with a vernier microscope. The diameter was measured at six places between the knife edge traces with a micrometer and the measured resistance values were corrected to correspond with specimens measuring 25 cm. $\times$ 1·5 mm. at room temperature, or the apparent specific resistance was calculated, assuming the room temperature dimensions. The values obtained, which were plotted against specimen composition, may thus not be regarded as absolute values, but since the important aspect of the work concerned the relative resistivity changes with alloy composition over narrow composition ranges, it was considered justifiable to neglect the effect of difference in specimen dimensions between room temperature and that of the experiment. The accuracy of the apparent specific resistance values depends essentially upon the

* Under the conditions employed, the best results were obtained by polishing for 10 sec. at 47 amp./sq. dm., with an applied voltage of 1·5 volts and an anode-cathode separation of 1·25 cm.

* The dimensions of the oil baths used were 16 × 8 × 6 in., and in general it proved convenient to connect three specimens in series in each bath. The oil used was "F" grade tempering oil (E. Vaughan and Co. Ltd.); it had a high flash point, did not "crack" at the temperatures of the experiments, and was without action on the metallic specimens.

measurement of the specimen diameter, and it is estimated that, in general, an overall accuracy of 0·4% in apparent specific resistance was attained for the alloys used in the present work. For tin itself, the reproducibility was lower than for the alloys. Several extruded samples which had been annealed at about 150° C. were examined; for ten samples extruded cold a variation of apparent specific resistance from 19·086 to 19·444 microhm. cm. was observed, while five samples extruded at 90° C. gave values from 19·067 to 19·661 microhm. cm. Although the cause of these variations was not investigated in detail, since highly reproducible results were obtained for the alloys, it is probable that the lack of reproducibility for pure tin was associated with preferred orientation and a relatively large grain size in the annealed extruded samples. The grain sizes of the alloy wires examined were considerably smaller than those of the pure tin samples, the resistances of which were thus more likely to vary from the statistical norm characteristic of a completely random grain orientation.

For the determination of the variation of apparent specific resistance with temperature, the apparatus illustrated in Fig. 2 was used. The specimen took the form of 20 cm. of wire wound into a coil, with which a thermocouple could be brought into contact. Current and potential leads were furnished by soldering a loop of copper wire to each end of the specimen, as shown: the alloy itself was used as the solder except for tin-thallium alloys, where pure tin was substituted. The glass tube in which the specimen was enclosed was filled with nitrogen, after evacuation, to ensure good thermal exchange, and was in turn enclosed in a copper sheath. The whole assembly was slowly heated or cooled in an electrical resistance furnace, readings being taken every 4 or 5° C.

The Binary Systems: Previous Work and Experimental Results

The System Tin-Cadmium

According to Hanson and Pell-Walpole,[1] the maximum solid solubility of cadmium in tin is 1·1 wt.-% at 132·5° C.

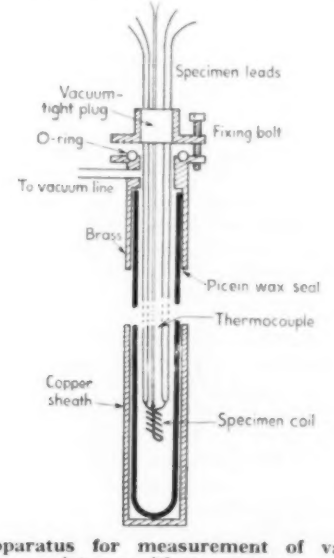

Fig. 2.—Apparatus for measurement of variation of resistance with temperature.

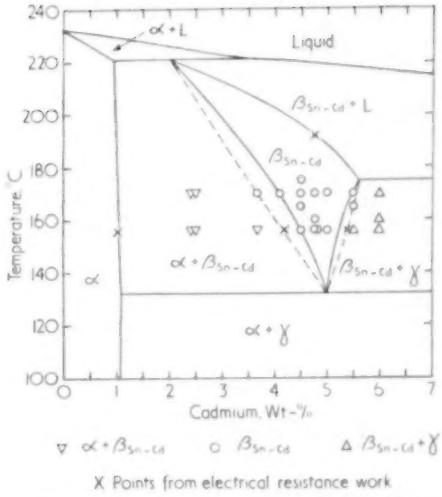

Fig. 3.—Tin-rich portion of tin-cadmium equilibrium diagram: full lines—Hanson and Pell-Walpole[1]; broken lines—present work.

The primary solid solution, α, is succeeded, as the cadmium content increases, by a tin-rich phase, $\beta_{Sn\text{-}Cd}$, the crystal structure of which is simple hexagonal.[4] This is formed peritectically from α at 223° C., and decomposes eutectoidally, into α and the primary solid solution of tin in cadmium, at 132·5° C.; the eutectic composition is given as 5 wt.-% cadmium. The $\beta_{Sn\text{-}Cd}$ phase cannot be quenched, but decomposes rapidly into α and the cadmium-rich solid solution, γ, giving rise to confused microstructures which are difficult to interpret. The tin-rich portion of the equilibrium diagram proposed by Hanson and Pell-Walpole is reproduced as Fig. 3, in which the phase boundaries are denoted by full lines.

To check this diagram before working on the ternary alloys, metallographic and electrical conductivity experiments were carried out. Ten alloys were annealed for 17 days at 170° C. and quenched into water. The metallography was difficult, but unambiguous results were obtained by careful preparation. The decomposed $\beta_{Sn\text{-}Cd}$ structure etched darkly, and small amounts of γ were not easy to detect. Examination for traces of γ in quenched samples was therefore carried out in the unetched condition, when the γ particles were observed in relief, with characteristic changes of tint on altering the focussing of the microscope. The most useful etching solution for $\beta_{Sn\text{-}Cd}$ and ($\alpha + \beta_{Sn\text{-}Cd}$) alloys was a mixture of glycerol, acetic acid and nitric acid in the ratio of 4 : 1 : 1 by volume; the α grains in two-phase alloys appeared much lighter than the decomposed $\beta_{Sn\text{-}Cd}$. The results are plotted in Fig. 3, together with those of similar experiments at 156° C. To confirm these results, and especially to make sure that γ had been adequately distinguished in the quenched samples, the alloys with 4·48 and 5·51 wt.-% cadmium were etched in the annealing furnace at 165° C. before quenching, the etching reagents being either gaseous hydrochloric acid or the glycerol : acetic acid : nitric acid mixture mentioned above. Both alloys corresponded with a typical polygonal-grained homogeneous microstructure, showing them to consist of $\beta_{Sn\text{-}Cd}$ at the quenching temperature. Alloys containing 4·74 and 6·01 wt.-% cadmium were similarly etched at 160° C., and were in the $\beta_{Sn\text{-}Cd}$ and

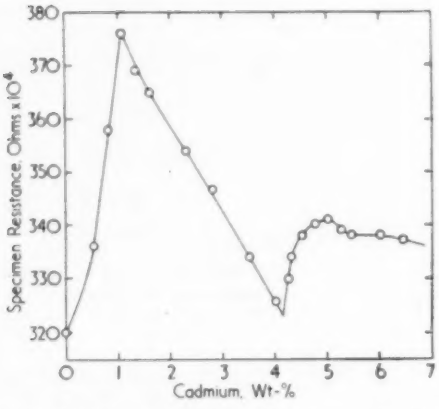

Fig. 4.—Variation of resistance with composition for binary tin-cadmium alloys, at 156° C.

($\beta_{Sn\text{-}Cd} + \gamma$) fields, respectively. These results were in agreement with those for quenched alloys, and are included in Fig. 3. The general indication is that the range of homogeneity of $\beta_{Sn\text{-}Cd}$ is a little greater than reported by Hanson and Pell-Walpole.

A further alloy series was examined by the electrical conductivity method. Twenty-two alloys containing up to 7 wt.-% cadmium were cast under glycerol, extruded, and annealed for 1 week at 150° C. The wires were quenched into cold water as required, mounted in the resistance apparatus, and the resistances were measured as previously described, at a temperature of 156° C. The graph of resistance against composition is reproduced in Fig. 4; its form is in general agreement with previous work, and, following previous interpretations,[1] indicates a solid solubility of cadmium in tin at 156° C. of 1·07%, and that the $\beta_{Sn\text{-}Cd}$ phase at this temperature extends from 4·2–5·4 wt.-%. The extent of the solid solution is thus confirmed, but for $\beta_{Sn\text{-}Cd}$ both the metallographic and conductivity methods suggest a slightly greater homogeneity range than in the diagram of Hanson and Pell-Walpole. The new $(\alpha + \beta_{Sn\text{-}Cd})/\beta_{Sn\text{-}Cd}$ and $\beta_{Sn\text{-}Cd}/(\beta_{Sn\text{-}Cd} + \gamma)$ phase boundaries are shown in Fig. 3 as broken lines.

Several alloys were slowly heated at rates varying from 2·5–0·5°/min. and resistance measurements were taken at regular temperature intervals. $(\alpha + \gamma)$ alloys showed a marked isothermal increase in resistance at temperatures of 133°–136° C., while a reverse change took place on cooling at slightly lower temperatures. The mean of the results of a number of experiments was in agreement with the eutectoid temperature plotted in Fig. 3, which may therefore be accepted. The experiments showed that the temperature coefficient of resistance C* is 0·0033 for the $\beta_{Sn\text{-}Cd}$ phase (135°–175° C.), and 0·0038 (20°–120° C.) for the $(\alpha + \gamma)$ phase mixture.

Dilatometric experiments were carried out with an alloy containing 4·74 wt.-% cadmium. Isothermal expansion occurred at the eutectoid temperature on heating; though some hysteresis occurred, the reverse change occurred at only slightly lower temperatures. The average change of length at transformation in eight experiments was 0·08%.

To provide information on rates of attainment of equilibrium and rates of decomposition of $\beta_{Sn\text{-}Cd}$, further work was carried out in the conductivity apparatus. An alloy of 4·8 wt.-% cadmium, initially in the as-extruded condition, was held at 156° C. and resistance measurements were made at regular intervals. A steady resistance was reached after approximately 20 hours at 156° C. It was, however, thought advisable to employ much longer times than this in annealing work. To examine the decomposition of $\beta_{Sn\text{-}Cd}$, four specimens of a 5 wt.-% cadmium alloy were annealed to equilibrium at 174° C. and rapidly quenched. The wires were immediately inserted in the resistance apparatus, and isothermal resistance-time curves were determined at 20°, 50°, 70°, 106° and 125° C. At room temperature a rapid decrease of resistance occurred, which was nearly complete in 50 minutes: the change occurred more rapidly at the higher temperatures, and at 70° and 106° C. interesting two-stage curves were obtained, discussion of which is not appropriate to the present work. The experiments showed, however, that changes were already occurring in the $\beta_{Sn\text{-}Cd}$ phase immediately after quenching, and emphasised that, in any electrical resistance experiments on quenched material, a standard time must be allowed to elapse between quenching and measurement of resistance in order to obtain strictly comparable results. Attention was paid to this point in certain experiments on the ternary alloys described below.

In the dilatometric work with the 4·74 wt.-% cadmium alloy, the specimen was observed to undergo an apparent contraction, due to its collapsing under the weight of the dilatometer, at 190·5° C. This temperature may be identified with the solidus temperature for this composition, in exact agreement with Hanson and Pell-Walpole.[1]

The System Tin-Zinc

In this system, a simple eutectic is formed at 8 wt.-% zinc and 198° C. between the tin-rich and zinc-rich solid solutions. The solid solubility of zinc in tin is not uniquely defined, and values in the literature vary from almost zero to 2·5 wt.-% zinc.[5-8] Several binary tin-zinc alloys, with compositions in the range 0·5–20 wt.-% zinc, were therefore prepared and extruded into wire, and homogenised for 2 days at 185° C. After annealing for 2 days at 156° C. in the electrical resistance apparatus, the resistances were determined at this temperature. The specific resistance decreased non-linearly, as the zinc content increased from 0·5–20 wt.-%, and the value for the 0·5% alloy was slightly but significantly higher than that for pure white tin. It was concluded that the solid solubility of zinc in tin was less than 0·5 wt.-% at 156° C.; this was confirmed by metallographic examination of all the specimens, as subsequently quenched from 156° C., which contained particles of the zinc-rich solid solution, δ, visible in relief on well-polished, unetched sections, with a brownish coloration. Etching with a 2% solution of nitric acid in alcohol confirmed the presence of δ, which appeared as a grey constituent, assuming a needle-like form as the volume percentage present increased. Of previous estimates of the solid solubility of zinc in tin, therefore, that of Homer and Plummer,[8] 0·325 wt.-% at the eutectic temperature, is to be preferred, since only very small amounts of δ were observed in the present work at 0·5% zinc.

The System Tin-Thallium

The accepted equilibrium diagram indicates that a eutectic is formed, at 42 wt.-% thallium and approxi-

* $C = \frac{1}{R_{20}} \cdot \frac{\triangle R}{\triangle T}$ where R_{20} is the resistance of the specimen at 20°C, and $\triangle R$ is the change in resistance over the temperature interval $\triangle T$.

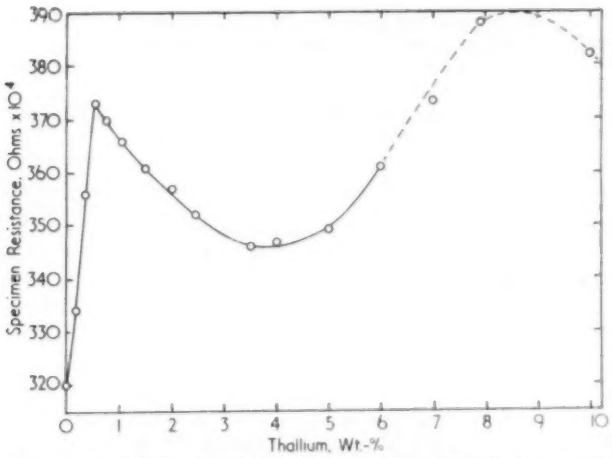

Fig. 5.—Variation of resistance with composition for binary tin-thallium alloys, at 156° C.

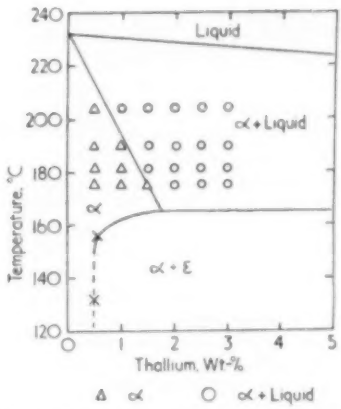

Fig. 6.—Tin-rich portion of tin-thallium equilibrium diagram.

mately 165° C., between almost pure tin and a moderately extensive solid solution of tin in thallium.[9] Meara[10] has suggested, on the basis of magnetic susceptibility experiments, that an intermediate phase occurs. This suggestion is not supported by the X-ray investigation of Ireton, Blewitt and Allen[11] who found evidence only of the existence of the two terminal solid solutions: they pointed out that, whereas the critical temperature for superconductivity usually remains constant in a two-phase region, in this system the critical temperature varied in a manner usually associated with solid solution alloys. Further, the lattice spacings of the tin-rich solid solution varied within the two-phase region, reaching a maximum value of 5·830 Å at approximately 42 wt.-% thallium.

In view of these uncertainties, a limited investigation was undertaken in the present work. A metallographic survey of eight alloys annealed *in vacuo* for 5 weeks at 150° C. and 132° C. was inconclusive. Difficulties arose owing to the softness of the alloys and loss of thallium on exposure to air, the ingot becoming rapidly covered with a fine powder of thallium oxide. This could be prevented by storing out of contact with air, but difficulties in mechanical or electrolytic polishing, and in etching, suggested that electrical resistance or X-ray methods would be more reliable. Accordingly, fifteen alloys, with compositions between 0·21 and 10·02 wt.-% thallium, were cast *in vacuo*, and extruded. After annealing the wires for some days at 156° C., the resistances were determined at that temperature; the wires were then quenched and the resistances were measured at 22° C. in a suitable thermostat. The specimens were remelted, re-extruded and resistance measurements made after annealing at 132° C. The curves of resistance against composition were similar in form for all three temperatures; Fig. 5 summarises the results for the 156° C. isothermal. The initial steeply rising portion corresponds with the tin-rich solid solution, which thus reaches a value of 0·54 wt.-% thallium at both 156° C. and 132° C. The remainder of the curves is not typical of an equilibrium two-phase region; a linear decrease in resistance (0·54–3·25% thallium at 156° C.; 0·54–1·50% at 132° C.) is followed by a non-linear increase as the thallium content increases towards 10 wt.-%.

To determine whether solid state transformations were present, in addition to that expected from the allotropy of thallium, thirteen alloys containing from 3·92–75·70 wt.-% thallium were prepared in wire form, and their electrical resistances measured as a function of temperature. Alloys were annealed in the apparatus for one day at 150° C. and slowly cooled to room temperature at 0·5° C./min. Resistances were determined at 5° intervals on both cooling and subsequent heating. All specimens showed a linear resistance/temperature relationship up to 80° C., after which the temperature coefficient increased. This sharp change in direction became more pronounced as the thallium content increased, and corresponds with the crystal structure change from cubic to hexagonal in the saturated solid solution of tin in thallium. On reaching temperatures in the region of the eutectic temperature, the resistance/temperature curves changed direction sharply, and the alloy wires disintegrated under their own weight. The temperature of disintegration was 165° C., in excellent agreement with previous estimates of the eutectic temperature. The temperature coefficients of resistance (0°–80° C.) for the alloys also showed behaviour untypical of an equilibrium two-phase region; the value decreased with increase in thallium content up to 10 wt.-%, then increased to a maximum at 20 wt.-%, subsequently decreasing with increase of thallium content to the limit of the composition range investigated.

Confirmation of the solid solubility of thallium in tin was obtained by annealing and quenching experiments to establish the α solidus; small amounts of chilled liquid were recognised without ambiguity in quenched microsections. The results are shown in Fig. 6, and the maximum solubility may be estimated as 1·7 wt.-% thallium at 165° C.

The peculiar variation of resistance and its temperature coefficient with composition in the apparent two-phase region prompted an X-ray examination; powder diffraction photographs from many of the alloys used in the resistance work, however, corresponded with the presence of the tin-rich and thallium-rich solid solutions only. To investigate lattice spacing relationships, eleven new alloys with thallium contents from 1·03–25·03 wt.-% were prepared, and annealed at 77° C. (i.e. below the transformation due to the allotropy of thallium) for 5 weeks. To avoid possible loss of thallium, annealing was carried out, not in evacuated glass tubes, but under

dibutyl phthalate.* After quenching, filings were prepared and the necessary strain relief was given for 1 hour at 77° C. Considerable scatter in the lattice spacings was observed: the *a* spacing of the tin-rich phase in the 1·89% alloy was 5·8212 kX, while that for the 10·01% alloy had decreased to 5·8150 kX. Corresponding variations occurred in *c* and *c*/*a*. After a further 7 weeks annealing out of contact with air, however, all alloys containing up to 10·01% thallium corresponded with lattice spacings for the *a* phase which were constant at 5·8193–5·8195 kX for *a* and 3·1743–3·1744 kX for *c*. Scatter was still observed for alloys containing larger amounts of thallium, and a total anneal of 21 weeks was necessary to bring the *a* and *c* spacings of the tin-rich phase in an alloy containing 18 wt.-% thallium to the values quoted above. With sufficient annealing all lattice spacings for the tin-rich phase were brought into agreement, showing that very long annealing times are required to establish equilibrium in alloys containing more than 10% thallium. This accounts for the variability of the lattice spacings in the two-phase region in the work of Ireton, Blewitt and Allen, and for anomalously variable physical properties, as reported by Meara. It is suggested that the slow approach to equilibrium also accounts for the peculiar form of the isothermal resistance/composition curves obtained in the present work, and illustrated in Fig. 5: apart from the sharp peak corresponding to the solubility limit, the exact forms of the curves in the two-phase region are of little significance. The tin-thallium system is thus of the simple eutectic type; the maximum solid solubility is 1·7 wt.-% of thallium in tin at the eutectic temperature, falling sharply to 0·54 wt.-% at 156° C.

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This system has recently been re-examined by Blade and Ellwood,[2] whose conclusions were verified by limited independent work in the authors' laboratory, except for the homogeneity range of the $\gamma_{Sn\text{-}In}$ phase. As pointed out by Raynor and Goulding in discussion of this paper, the variation of lattice spacing with composition within the $\gamma_{Sn\text{-}In}$ region, when combined with the measured lattice spacings in two-phase alloys, indicates that the phase exists between the limits 10·1–23·4 wt.-% indium at 50° and 105° C. According to Blade and Ellwood, the solid solubility of indium in tin is approximately 6 wt.-% indium at 50° C., with which value the present authors' determination of 5·8 wt.-% by lattice spacing methods is in reasonable agreement; the maximum solubility (8 wt.-% indium) occurs at 205° C., at which temperature the primary solid solution and the liquid react peritectically to form $\gamma_{Sn\text{-}In}$, of composition 9·3 wt.-% indium. The solidus line for $\gamma_{Sn\text{-}In}$ falls smoothly from 205° C. at 9·3 wt.-% indium to 116° C. at 23·4 wt.-% indium.

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The aluminium foundry industry thus has the sand casting process which goes back in antiquity, gravity die casting, which is nearly fifty years old, and pressure die casting, which in its present form is nearly twenty-five years old. It is against such a background that the study of trends in aluminium alloy founding has to be made.

The Trends

In many spheres, and particularly in engineering, mechanisation has become the basis of production. This has tended to turn craftsmanship from the field of actual production of the required articles to the provision of tools, both mechanical and electrical, by which the desired articles can be produced, in most cases more economically, and generally by less skilled operatives. The foundry is no exception: it is, therefore, readily understandable that the designer or engineer should lean towards either gravity or pressure die casting, as opposed to sand casting, for the aluminium alloy castings he may require for his product.

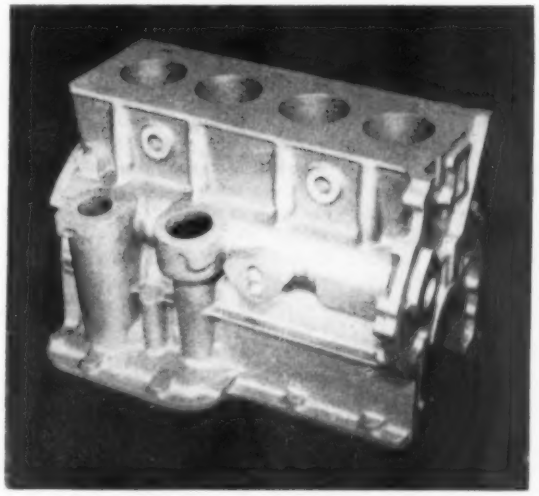

Fig. 1.—A cylinder block which could be gravity die cast using a sand core for the water jacket.

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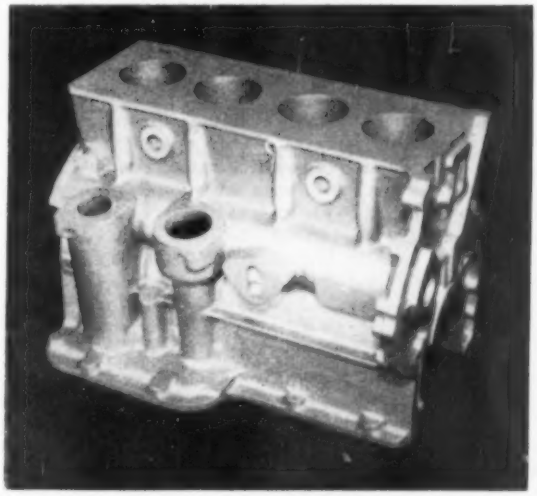

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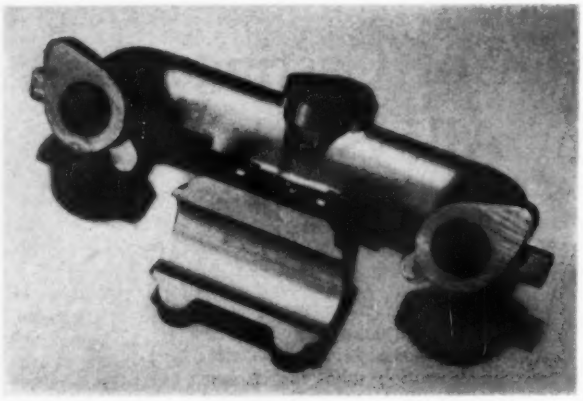


Fig. 2. A gravity die cast induction pipe using a sand core for the pipe bore.

To Gravity Die Casting

The move from sand casting to gravity die casting can be mainly attributed to economic reasons, especially where reasonably large quantities are envisaged. The process of production of castings from permanent moulds will always be less costly than sand casting, where a new mould must be made for each casting. To the economic advantages must be added the facts that the casting produced is cleaner, more accurate dimensionally, and, due to the chilling effect of the metal mould, of more homogeneous texture and closer grain than that produced from a sand mould. A further reason for the trend away from sand casting is the fact that the founder, by improved techniques, has been able to undertake much larger castings from permanment moulds than previously. To the foregoing could be added such further advantages as higher mechanical properties and the saving in metal and time due to smaller machining allowances; these are rather more accidental, or incidental, and can be considered as an additional bonus.

To Pressure Die Casting

The further trend from gravity to pressure die casting is a natural movement from the economic angle, but this is controlled more by quantities than the earlier case. This is mainly due to the higher cost of production of dies and clipping tools; also the cost of setting up on the die casting machine. The larger the quantity of castings required, the more economic will be the production, and these considerations have to be taken into account when deciding which process would prove to be of greater advantage.

Assuming that the quantities are right, the first essential is to adjust the design of the casting to obviate production difficulties in both die making and operation of the dies when production has commenced. In these enlightened days it is often unnecessary to make much modification to the drawings, as it is the custom for the designer to call in the die casting technician at an early stage in design if pressure die castings are envisaged. It is only when a complete changeover from gravity to pressure die casting is made that re-design has to take place.

To obtain the greatest advantage, both economic and technical, from the pressure die casting, a design suitable for the process is the first essential, so that the die can be designed and made to operate freely, without either distorting or stressing the resultant casting in any way. Secondly, the die casting technician should have a good knowledge of the purpose and function of the casting, so that the most suitable alloy can be recommended, and all unnecessary subsequent machining obviated. A further item of extreme importance from the economic angle is the question of dimensional limits and tolerances. Engineers and designers should grant the widest tolerances possible, and only call for fine limits on dimensions where these are essential. Where this is done, the founder can use that little extra taper in his dies, which will make all the difference between easy working with rapid output and difficult extraction from the dies and slow production. It will also enable the essentially fine tolerances to be maintained more effectively, and the life of the dies to be extended.

The Zinc Alloy Die Casters' Association, in co-operation with the Light Metal Founders' Association, has published a book of "Engineering Standards for Pressure Die Castings," which gives recommendations for aluminium, magnesium and zinc alloy die casting tolerances. All engineers and designers should make themselves acquainted with this publication if they desire to obtain the best casting possible at the most economic price. In connection with the study of these standards, it must be clearly understood that the limits quoted in them do not indicate the closest tolerance that can be obtained, but rather the optimum desirable to produce the best casting at the most economic price. The use of these tolerances, as a general rule, will enable the die caster to maintain any close limits more easily and more accurately. A further great advantage will be found in the increased die life.

The Processes

Sand Casting

The sand casting process has many advantages which are not possessed by the other two methods, among the foremost of which is the fact that more intricate shapes can be produced where this is essential. As the initial cost of patterns is less than the cost of producing metal moulds, sand castings will always be more economical for prototype work, and also where the quantities required are not large. For prototype work a further advantage is that wooden patterns can be modified much more easily than dies.

Where large quantities of castings are required, the question of maintaining dimensional accuracy is one of

Fig. 3. Transmission cases, gravity die cast with sand cores.

the difficulties of the process. With the use of wooden patterns, movements in the pattern can often upset the accuracy of the final casting. With metal pattern equipment conditions are better, but even with this, considerable wear can be, and is, occasioned by the abrasive action of the sand.

Gravity Die Casting

Except where the design of the casting is of a most complicated form, the changeover from sand casting to gravity die casting is generally of a fairly simple nature requiring in some cases slight modification only to enable a complete metal mould to be used. In many cases no modifications at all are required. There is, however, a third class where the necessary coring is of such a nature that metal cores cannot be extracted, for instance, jacketed castings or heavy undercuts, and in these cases it is often possible to use an outside die and employ sand cores for all interior work. In this way it is possible to produce more accurate castings than can be obtained by the sand casting process.

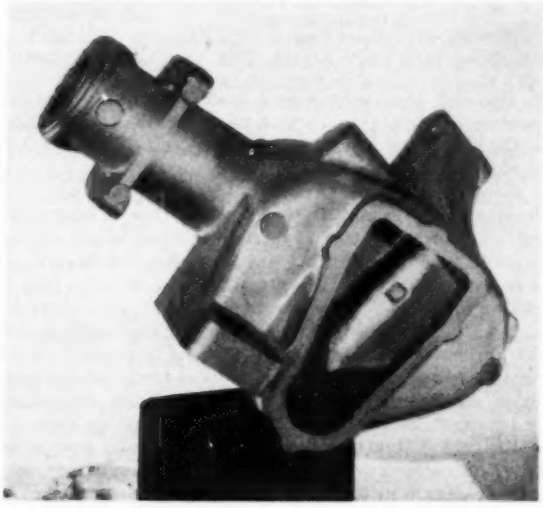


Fig. 4.—A steering gear box, gravity die cast using a sand core.

Gravity die castings offer to the engineer many advantages of a technical nature, apart from the greater dimensional accuracy, when compared with sand castings. These include higher mechanical strength, more ductility, and a closer grain structure due to the chilling effect of the metal mould. A large range of alloys can be used, so that the most suitable for the purpose can be selected, and, as in the case of sand castings, many of these can be finally heat treated to obtain the highest degree of strength in the casting. It is interesting to note that many cases exist where high strength, heat treated aluminium alloy die castings have replaced malleable iron castings with great success.

Pressure Die Casting

While gravity die casting can be stated to be one step in front of sand casting, pressure die casting comes into

Fig. 5.—A gravity die cast housing produced from an all-metal mould

a completely different sphere. Many people may claim that it is not a foundry process at all, which is possibly correct as the only operation which is also common to the processes referred to previously is the melting of metal. The completion of the pressure casting process is nearer to metal pressing than casting, as the final product is the result of forcing the metal by means of a hydraulic press, into the mould or die, which is mounted in the press for this purpose. In view of the high pressures used, and also the chill of the mould or die, the structure of the casting is completely different from that obtained by either sand casting or gravity die casting. The time required for solidification of the metal by this process is extremely low, being almost instantaneous in some cases, to a matter of a few seconds in others. As a result of this sudden chilling, the mechanical properties of the casting also differ considerably from those obtained in castings made by the other processes mentioned. Generally speaking, the ultimate tensile stress is higher and the ductility lower.

To obtain full advantage of the pressure die casting process, the question of design of the casting must be closely studied, and its function in the complete unit must be understood, so that the most suitable alloy can also be selected. These two points are exceedingly important, as without a careful study of both, the resultant product may fall very far from the intended performance of the unit.

The size of casting that can be produced by this process is limited by the size of casting machine that is available, and while machines are generally increasing in size—and this has been particularly true during the last few years—limitation in size must still remain for some time yet.

The production of high grade castings by the pressure process is also limited to a few alloys which have been specially prepared for pressure die casting and thoroughly tested before being put into general production. A further point to be noted is that pressure die castings

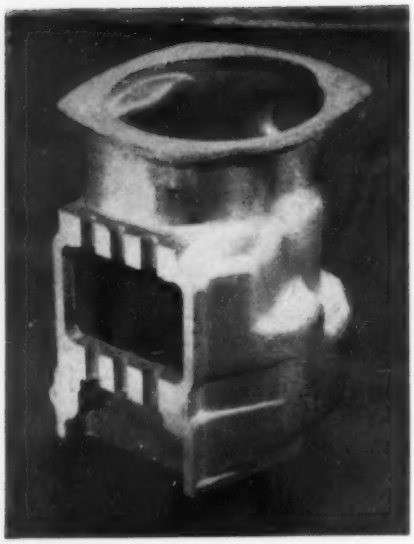


Fig. 6.—A well designed motor car gearbox produced from all-metal moulds.

Fig. 7.—A group of pressure die castings of simple and intricate design.

do not respond to heat treatment in the same way as sand or gravity die castings. Accordingly, up to the present time, all pressure castings are supplied in the as-cast condition.

Conclusions

The trend from sand casting to gravity die casting and from gravity die casting to pressure die casting is a universal one, being possibly more pronounced in the U.S.A. than in any other country, and much more pronounced than in Great Britain. The trend is, at the same time, definitely with us, and will continue to gain impetus as the benefits to be derived therefrom are demonstrated by experience of the use of each type of casting.

The foundry industry has a very important part to play in guiding this movement so that the final results give satisfaction all round. In the past, most jobbing foundries have produced castings to customers' designs, in the alloy specified, without knowing anything of the final use of the casting or the conditions under which it would be required to function. Here we can take a leaf out of the American foundryman's book, as the latter seems always to be conversant with the function of every casting he makes, and can make recommendations on processes and alloys. By this knowledge he is able to suggest the best method of production and the most suitable alloy and condition, whereby economy and quality can go hand in hand.

It has already become evident in this country that engineers and designers come into two classes, namely those who desire to dash forward into a new process without clearly understanding its limitations or its suitability for their own particular requirements; and on the other hand, those who are too cautious and are slow to move on to anything that is new.

The die casting specialists have, therefore, a most important duty to perform, not only in their own interests, but more especially in the interest of progress, by guiding the former type and encouraging the latter. To this end, they must gain a working knowledge of the function of each casting which they are asked to produce, so that they can advise on the most suitable method of production to obtain the desired results.

Many cases have already come to light where the designer has desired to produce, by the pressure die casting process, certain castings which would not live up to requirements under normal operating conditions. It is in such cases that the specialist must be very firm in guiding him to the most suitable method of production, so that the progress of the use of aluminium castings will not be retarded. This can very easily happen if the wrong process or an incorrect alloy is used. Progress in these matters is often made more rapidly by taking things in stages, as has been proved on many occasions in the past. To attain these ends the foundry technician may, on occasion, be wise to cultivate diplomacy to a greater degree in the future than has been necessary in the past.

Acknowledgment

The author desires, in conclusion, to express his thanks to the Birmingham Aluminium Casting (1903) Co., Ltd., for their assistance in supplying the illustrations.

Baker Perkins to Make Triulzi Machines

BAKER PERKINS announce that following agreement with A. Triulzi S.A.S., the leading Italian injection moulding and die casting machinery manufacturers, Triulzi machines will be built by Baker Perkins in Britain. The Triulzi range includes injection moulding machines of from $\frac{1}{8}$ oz. to 400 oz. capacity, and the die casting machines from 30 ton to 1,500 ton locking force. The range also includes machinery for laminating, deep drawing, hobbing, compression and transfer moulding, rubber moulding, etc. Initially the 1 oz. and 5 oz. injection moulding machines and the 120 ton die casting machine will be manufactured and other machines will be imported.

Clad Aluminium Alloys*

By F. C. Porter, M.A., A.I.M.

Aluminium Development Association

Whilst the aircraft industry remains the leading user of clad aluminium alloys, chemical engineering uses are increasing in importance, particularly as long and satisfactory experience is being gained in existing applications. The manufacture, properties and applications of these materials are discussed here and reference made to the use of cladding techniques for special products such as sheet for anodising or brazing purposes.

THE cladding of one aluminium alloy with another, or with pure metal, was first developed for aircraft applications. The highest strength alloy sheets then known had relatively poor corrosion resistance, and protection was given to them by rolling on a thin layer of pure aluminium. This had a higher intrinsic corrosion resistance, and also sacrificially protected any portions of the strong alloy which became exposed to corrosive environments.

Clad high strength alloys, used largely for aircraft and missile applications, still remain the major product in this field, but clad aluminium-magnesium-silicon alloys of medium strength are of importance in chemical engineering applications, such as beer barrels. The excellent resistance of the clad product to corrosive perforation is important in this type of application, and is the only reason for the existence of the clad aluminium-manganese alloy, where the core alloy is intrinsically of as good corrosion resistance as the cladding alloy. It is used mostly for applications where liquids may cause pitting corrosion of an unclad alloy.

Other clad products utilise a core of appropriate mechanical strength and a cladding with specific properties. An aluminium-silicon cladding facilitates brazing, avoiding time-consuming filler material insertion in complicated structures. The same material anodises to a decorative grey finish, sometimes utilised in conjunction with the silver anodising of pure aluminium. Pure aluminium cladding can also be brightened, then anodised to retain a mirror finish or lustrous appearance.

Sheet and plate products are most readily produced and widely used, but clad tubes, rod and extrusions are all commercially available products. Forgings and castings cannot be clad, but receive analogous corrosion protection by metal spraying. Coatings produced from the liquid or vapour phases (plating, hot-dip aluminising, vacuum deposition), together with metal spraying, are not discussed. Laminates in which either the core or the cladding is not an aluminium alloy are also excluded from consideration.

History

The original patent on this subject was granted to Parent[1] in 1898 : it claimed for a cladding of commercial purity aluminium on an aluminium alloy. The first commercial product was Alclad 17S[2] (aluminium cladding on a core containing 4% copper, ½% magnesium, ½% manganese) produced in 1928 following a patent by Dix[3] the previous year. Alclad 17S, which is related to the widely used British material HC 15 (B.S. 1470–7), has been largely superseded in the United States by other clad alloys (Table I).

Although aircraft (and latterly missiles) remain the major outlet for clad materials, chemical engineering applications have grown rapidly. As with steam engines, much was learned from the behaviour of the domestic kettle. The prototypes from clad sheet put into service in the late thirties restricted incipient pitting corrosion (due to some tap waters) to the clad layer, and by 1946 over 250,000 were in service with only five reported failures.[4] Manufacturing techniques for clad tubes had by then been developed, enabling entry into the potentially great market of heat exchangers and condenser tubes. In 1949 Dix reviewed the available materials and their properties.[5]

At this time unclad aluminium alloys were used with considerable success for beer barrels but, to take advantage of the much greater life possible with aluminium compared with wood, clad alloys were introduced in the late forties[6] and are now firmly established. Meanwhile the large war production surplus and scrap high strength alloys were being absorbed in clad products, notably for building purposes, such as the roofing and siding of 70,000 British prefabricated bungalows.[7]

Clad brazing sheet has only achieved significant usage in the present decade, since reliable and reproducible brazing techniques have become available. Similarly, the use of clad products for anodising stems from the need for a uniform and permanently attractive surface in the curtain-walling type of building construction : usage of clad products in decorative anodising for the automobile industry is still a development project. In all senses, however, the future is certainly bright.

Manufacture

During manufacture a metallurgical bond is obtained between cladding and core by what is essentially pressure welding. Scalping of the original ingots is necessary to remove surface segregation and defects such as oxide inclusions and laps. Relative surface movement of metal during production of the laminate then breaks up the oxide film on the original metal surfaces to give complete welding. This is shown by the diffusion of alloying elements across the boundary in subsequent heat treatment.

Sheet and plate are the most readily produced of all clad products. Originally, the core alloy was cast between sheets of wrought aluminium and the composite ingot then hot rolled.[3] Later developments, notably continuous casting, made for greater economy by fastening the cladding sheet and the core ingot together

* The materials discussed in this article have a cladding on one or both sides, usually about 5% of the total thickness.

TABLE I.—NOMINAL COMPOSITION AND PROPERTIES OF CLAD ALUMINIUM ALLOYS (U.S.A. SPECIFICATIONS)

Type of Product	Aluminium Association	A.S.T.M. Designation		Nominal Composition (%)							Minimum Cladding Thickness (A.S.T.M.)	Mechanical Properties*		
				Al	Cu	Si	Mn	Mg	Zn	Cr		0·2% Proof Stress (tons/sq. in.)	Tensile Strength (tons/sq. in.)	Elongation (% on 2 in.)
Sheet and Plate (A.S.T.M. B209)	Alclad 3003	Clad M1A	Core	Rem.	—	—	1·2	—	—	—	0·10 T (T = thickness)	7·1	8·5	5
			Cladding	Rem.	—	—	—	—	1·0	—				
	Alclad 3004	Clad MG11A	Core	Rem.	—	—	1·2	1·0	—	—	0·05T	—	16·9	4
			Cladding	Rem.	—	—	—	—	1·0	—				
	Alclad 2014**	Clad C841A	Core	Rem.	4·4	0·8	0·8	0·4	—	—	†	25·4	28·5	8
			Cladding	Rem.	—	0·7	—	1·2	—	0·25				
	Alclad 2024	Clad C142A	Core	Rem.	4·5	—	0·6	1·5	—	—	‡	17·8	27·6	15
			Cladding	99·5min.	—	—	—	—	—	—				
	Alclad 6061	Clad G81A	Core	Rem.	0·25	0·6	—	1·0	—	0·25	0·05T	14·3	17·0	10
			Cladding	Rem.	—	—	—	—	1·0	—				
	Alclad 7075	Clad Z062A	Core	Rem.	1·6	—	—	2·5	5·6	0·3	0·04T	27·6	32·1	8
			Cladding	Rem.	—	—	—	—	1·0	—				
Drawn Seamless Tube (A.S.T.M.B210 and B234)	Alclad 3003	Clad M1A	Core	Rem.	—	—	1·2	—	—	—	Nominal 0·10T inside only or 0·05T outside only	10·3	11·6	—
			Cladding	Rem.	—	—	—	—	1·0	—				
Bar, Rod and Wire (A.S.T.M. B211)	Alclad 5056	Clad GM50A	Core	Rem.	—	—	0·1	5·2	—	0·1	Nominal 0·20T	21·0§	23·2§	—
			Cladding	Rem.	—	0·7	—	1·25	2·0	0·25				
Extruded Tube (A.S.T.M. B235)	Alclad 3003	Clad M1A	Core	Rem.	—	—	1·2	—	—	—	Nominal 0·10T inside only	2·2	6·0	—
			Cladding	Rem.	—	—	—	—	1·0	—				

* Specified minima for 16 gauge material in strongest condition.
† For thicknesses of 0·062 in. and under—0·05T.
For thicknesses of 0·063 in. and over—0·025T.
§ Standard applicable only for 0·120 in.—0·192 in..
** Related to 268 Alclad in Canada.
‡ For thicknesses of 0·024 in. and under—0·10T.
For thicknesses of 0·025 in. to 0·039 in.—0·075T.
For thicknesses of 0·040 in. to 0·099 in.—0·05T.
For thicknesses of 0·100 in. and over—0·025T.

mechanically and bonding entirely at the hot rolling stage.

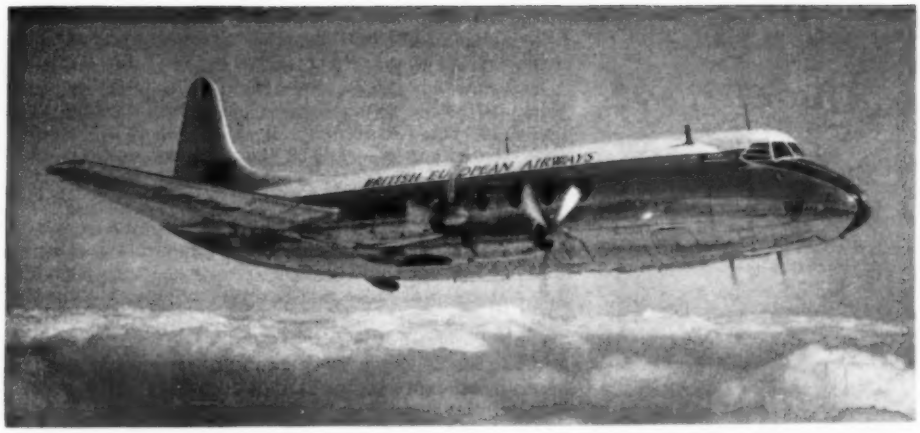
Anodising quality sheet and strip can be produced by cladding techniques. Some possible defects and their remedies, in material intended for anodising, have been discussed by Brace.[8] Even response to brightening is only obtained with working of the metal to break down the ingot cast structure and with maximum homogenity of alloying element distribution. In an unclad alloy this may largely be achieved by pre-extrusion of the ingot. Mass production techniques, however, are tending to favour a clad product even though the cladding may be—but rarely is—of the same composition as the core. The cladding alloy ingot is carefully homogenised and heavily worked prior to hot rolling in the composite slab. The final thin cladding layer will have received the requisite working and treatment to make the product of anodising quality although the core has required no costly special care.

Cladding by extrusion is a more difficult engineering process, a fact reflected by the paucity of published information. For exterior cladding, the core alloy is in effect extruded through a disc of the cladding alloy.

TABLE II—COMPOSITION AND SPECIFIED PROPERTIES OF CLAD SHEET AND PLATE ALUMINIUM ALLOYS (U.K.)

D.T.D. Specification.	Related B.S. "L" Series	Related B.S. 1470 or B.S. 1477		Composition (D.T.D.) (%)										Minimum Mechanical Properties (D.T.D.)		
				Al	Cu	Mg	Mn	Si	Zn	Cr	Fe	Ni		0·1% Proof Stress (tons/sq. in.)	Tensile Strength (tons/sq. in.)	Elongation (% on 2 in.)
710 A	L 72	HC15W HC14T HPC14T	Cladding	99·7 min.												
			Core	Rem.	3·8–4·8	0·55–0·85	0·4–1·2	0·6–0·90						15	25	15
746 A	L 73	HC15WP	Cladding	99·7 min.												
			Core	Rem.	3·8–4·8	0·55–0·85	0·4–1·2	0·6–0·90						21	27	8
5030		HPC15W	Cladding	99·7 min.												
			Core	Rem.	3·8–4·8	0·55–0·85	0·4–1·2	0·6–0·90						15*	25*	12
5040		HPC15WP	Cladding	99·7 min.												
			Core	Rem.	3·8–4·8	0·55–0·85	0·4–1·2	0·6–0·90						22*	27*	8
5060 A			Cladding	Rem†					0·8–1·2							
			Core	Rem.	0·3–1·5	2·2–3·2	‡		5·2–6·2	0·08–0·25 ‡				26*	31*	6
5070			Cladding	99·7 min.												
			Core		1·8–2·7	1·2–1·8					0·9–1·4	0·8–1·4		20	25	6

† Cladding made using aluminium of 99·7% minimum purity.
‡ Cr + Mn 0·18–0·50%.
* Plate ½ in.–1 in. has proof and tensile values 1 ton higher on core material only.
NOTE: D.T.D. 710A supersedes D.T.D. 610B (obsolete) and D.T.D. 746A supersedes D.T.D. 546B and D.T.D. 706 (obsolete)
NOTE: The cladding thickness on each side of the core shall be about 2% of the total thickness on D.T.D. 5030, 5040 and 5060A; on other alloys it shall be 5%.



Courtesy of Vickers Armstrongs Ltd.

Fig. 1.—Vickers Viscount, in which the aircraft skin and some internal sheet are of clad high strength alloys.

Interior cladding of tubes needs cladding around the extrusion mandrel. In either case the cladding thickness is variable along the extruded length and across the section. This has led to the introduction of longitudinally seam welded tubes from clad strip.

The finer dimensional tolerances of drawn tube are normally obtained by drawing down extruded clad tube. A composite product can also be obtained by drawing down a slightly oversize tube of the cladding alloy on to the core alloy tube, but there is insufficient working to ensure full metallurgical bonding and the product has limited applications.

Material Specifications

The aircraft clad alloys have been the subject of specifications in many countries (Tables I and II). These fall into two groups: (*a*) aluminium or alloy cladding on a core containing about 4% copper, with magnesium and manganese: some also have silicon added; and (*b*) aluminium–1% zinc cladding on a core containing about 6% zinc, 3% magnesium and 1¼% copper. The former group includes both naturally and artificially ageing alloys: the latter group is only of value when artificially aged after solution treatment.

The specified purity of aluminium used in the cladding of these and other alloys varies from 99·3 to 99·7% min. aluminium, for no apparent technical reason: 99·7% purity would be appropriate for most un-alloyed claddings. In general the cladding is not designed to contribute to the strength of the product, but Alclad 2014 is an exception, as is the clad aluminium-magnesium alloy (used mainly for wire mesh). In the U.S.A. the lower-strength clad alloys are also nationally specified (Table I), but clad sheets for reflectors and for anodising and brazing purposes are designated by individual company standards. The thickness of cladding used is usually 5% of total thickness. Some variations are given in Tables I and II, while one manufacturer offers the aluminium-zinc-magnesium-copper alloy with only 1½% of cladding for thicknesses greater than 0·188 in. In all clad products a tolerance of ± 20% of average cladding thickness is typical of manufacturers' specifications. For many applications, cladding on one side only would be sufficient but, except in the case of tubes, this is not common practice, due to the liability of errors occurring during subsequent fabrication.

No exact comparison can be drawn between British and American alloys, but in the highest strength group D.T.D. 687A and Alclad 7075 have similar properties. In the aluminium-copper-magnesium-manganese group there is scope for a British alloy with around 1·5% magnesium, as the comparable American alloy is used to some extent in this country.

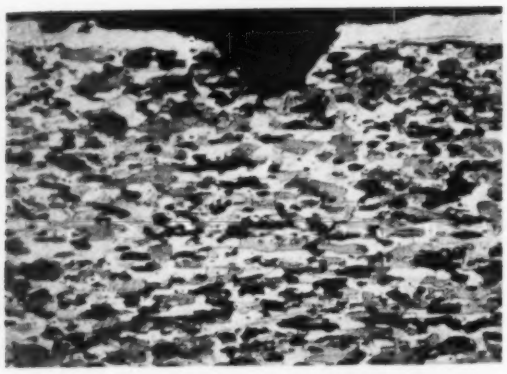
Mechanical Properties

For aircraft purposes fatigue and corrosion fatigue properties are of paramount importance. Difficulty arises in simulating service conditions in tests, the most useful results probably being the fatigue life determined by applying some thousands of load cycles each day to specimens otherwise exposed to atmospheric weathering. Recent tests of this type[9] compared the results with fatigue tests involving no atmospheric exposure. Exposed unclad 2024 and 7075 alloys had only one third the life of unexposed material. For fully heat treated Alclad 7075 the figure was two thirds, while there was no significant difference with Alclad 2024. This effect thus far outweighs the well-known finding that in the ordinary laboratory flexure tests the life of clad materials is usually about 25% lower than that of the corresponding unclad materials.

The stress-strain curves for clad materials show a change of slope in the normally linear portion due to the coating yielding—most notable when the coating is heavily worked. The resulting difference is of relatively little significance in design calculations. The tensile strength of clad material is very slightly lower than that of unclad material.

The formability of alloys is increased by the ductile coating. Scratches within the cladding have virtually no effect on either formability or proof stress of the aluminium-copper type alloys, but slightly reduce these properties in the aluminium-zinc-magnesium-copper alloys[10] which are known to be notch sensitive. The forming, notably dimpling, of this latter type of alloy[11] required much development work in the early stages, but techniques are now well established.

The softness of the cladding is, however, disadvantageous in that metal is too readily removed during polishing, e.g. of an aircraft fuselage, to expose core metal and necessitate replacement of the sheet. Although thicker claddings can be used, at some expense in strength, it would appear desirable to increase the hardness of the cladding. Prati,[12] for example, has suggested a 1% manganese addition to the aluminium–1% zinc cladding on the aluminium-zinc-magnesium-copper alloys.



Courtesy of Aluminium Company of America.

Fig. 2.—Cross section of aluminium-copper-manganese-magnesium clad sheet, showing electrolytic protection of core (exposed by deep scratch), after six years in New Kensington industrial environment. Etch HCl-HNO_3-HF. × 100.

Corrosion Resistance

The corrosion resistance of aluminium is high and adequate for most applications. Certain alloying elements, notably copper, which are needed to give high strength, lower the corrosion resistance and make protective measures desirable in many applications.

The effectiveness of cladding in increasing atmospheric corrosion resistance is shown by 20-year tests carried out by the American Society for Testing Materials.[13] Alclad 17S sheet (99·3% min. aluminium cladding), 0·035 in. thick was exposed in the naturally aged condition. At the most severe marine environment—La Jolla, Southern California—the loss of tensile strength after 20 years was under 6%, compared with 56% for the unclad alloy. At all other industrial and marine sites a similar or lower loss of strength occurred. Separate tests on artificially aged Alclad 17S and naturally aged Alclad 2024 showed no significant loss of elongation after the same time.

The most appropriate cladding for each core alloy has been extensively investigated.[14] The cladding must be of good corrosion resistance, yet sufficiently anodic to the core to protect the latter when it becomes exposed, preferably over a gap such as might occur in practice through scratching or through corrosion. Table III indicates the range of electrode potentials for a typical test solution. The potentials and their relative order may alter from solution to solution, however, so a margin of at least 0·05 volts should exist between core and cladding (the cladding being more negative) in any specific test. Most aluminium-copper-magnesium-manganese alloys are adequately protected by a grade of unalloyed aluminium. With the aluminium-zinc-magnesium-copper alloys, the higher zinc and lower copper make the alloy more electronegative (see Table III) and 1% zinc must be added to the cladding to ensure electrochemical (cathodic) protection of the core. It should be noted that these latter alloys are always used in the fully heat treated condition, when they are less susceptible to stress-corrosion than in the solution treated form.[14]

TABLE III—ELECTRODE POTENTIALS OF ALUMINIUM ALLOYS AND COMPOUNDS (AFTER DIX[5]) (0·1 N CALOMEL SCALE, IN AQUEOUS SOLUTION CONTAINING 53g./l. NaCl AND 3g./l. H_2O_2).

Alloy or Compound	Potential (volts)
Aluminium + 1% Zn in solid solution (7072)	−0·96
Annealed 7075	−0·94
Solution treated 7075	−0·88
Aluminium + 4% Mg in solid solution	−0·87
Aluminium	−0·84
99·3% (min.) Aluminium (cladding of Alclad 2024)	−0·83
Aluminium + 1% Mg_2Si in solid solution	−0·83
Aluminium + 1¼% Mn (3003)	−0·83
Fully heat treated 7075	−0·81
Fully heat treated 2014	−0·78
Aluminium + 4% Cu in solid solution	−0·69
Naturally aged 2014 or 2024	−0·68 to −0·70
$CuAl_2$	−0·53

Chemical engineering applications usually require material with resistance to perforation. Neutral aqueous solutions which contain chlorides, temporary hardness, dissolved oxygen and a trace of copper—such as most tap waters—will cause localised pitting of all aluminium alloys.[15] Clad material (such as aluminium-zinc cladding on aluminium–1¼% manganese core) gives excellent service, as although the aluminium-zinc cladding pits readily and exposes the aluminium–1¼% manganese core locally, the latter receives cathodic protection. Tests have shown times to perforation ranging from 4 to 60 times as great for the clad as for the unclad alloy.[4, 16] A low copper content of the core (as is normal commercial practice) is usually protected by 1·0% zinc in the cladding, but it might be preferable to require a nominal 1·2% zinc in the cladding to ensure cathodic protection of the core in all aqeous solutions likely to be encountered. When aluminium pits, the solution under the mound of corrosion product becomes markedly acid and this, together with dissolution of copper from the core, may well affect the relative potentials of the metals: further fundamental studies are needed.

The voluminous corrosion products from the aluminium-zinc alloys could theoretically cause trouble in blocking narrow pipes or unseating valves, but service reports have not shown this to be the case. Nevertheless voluminous corrosion products are alarming, especially to the layman, so a super-purity aluminium cladding has been developed and used successfully for kettles in a soft water, preventing both pitting and staining. The required potential difference between cladding and the aluminium–1¼% manganese core was in this case successfully attained by increase of copper in the core.[17]

Heat Treatment

The high strength materials develop maximum strength only after solution treatment and natural or artificial ageing. Treatment of clad and unclad materials[18] are in most respects similar, but three additional factors are relevant. With clad alloys it is necessary to maintain the cladding anodic to the core (see Table III) and prevent excessive diffusion of alloying elements from core to cladding. Conversely, however, it is slightly less important to maintain the core with an intrinsically high corrosion resistance.

In North American practice it is considered permissible to utilise a relatively slow quench (e.g. in oil) from solution treatment (to reduce distortion) with clad aluminium-copper-magnesium-manganese alloys, notably with those which are subsequently artificially aged;[5] in this country it is not generally accepted practice. The slow quench reduces electrolytic protection and gives localised precipitation at grain boundaries in the core, rendering it susceptible to intergranular corrosion, if exposed. With the American aluminium-zinc-magnesium-copper-chromium alloys, a slow quench cannot be tolerated because of loss of mechanical properties, but the similar British alloy containing manganese may be quenched in oil.

Diffusion between core and cladding only occurs to a

significant extent above 400° C., i.e. during solution treatment or annealing. The extent of diffusion depends only on time and temperature, so greater percentages of cladding are specified on thin gauge materials. Diffusion will occur preferentially at grain boundaries, so thicker coatings are specified on the aluminium-copper-magnesium-manganese alloys which can be susceptible to intergranular attack. Re-solution treatments of these alloys must be limited in number,[19] depending on cladding thickness, to avoid excessive diffusion. Clad aluminium-zinc-magnesium-copper alloys are less affected by diffusion, and the effect of copper is offset by the zinc and magnesium. Diffusion rates are reduced by addition of 1% manganese to the cladding.[12]

In all alloys diffusion creates a layer of metal intermediate in potential between core and cladding: corrosion tends to spread sideways before penetrating the diffusion layer (Fig. 2), which hence gives additional electrolytic protection to the core. Cladding having a large grain size can arise from heat treatment of sheet which has received a critical amount of cold work: the main disadvantage is the surface appearance after working—the characteristic "orange-peel" effect.

Applications

Aircraft and Missiles

The original clad materials were developed for the aircraft industry, and this has remained the main outlet for high strength clad materials. It is estimated that over 90% of the sheet used is clad both for the aircraft skin and for interior sheet work. The most stressed parts are in the aluminium-zinc-magnesium-copper type alloys. Attempts to produce still stronger alloys have met with only limited success, due to residual internal stress and to stress-corrosion tendencies. The usage of alloys with copper as the major alloying element is more complex. While L72 and L73 are widely used in Great Britain, several leading British aircraft contain material made to the American Alclad 2024 specification (which has no exact British equivalent) in the belief that it has superior fatigue properties.

Clad aluminium-magnesium-silicon alloys find limited aircraft structural use where stiffness rather than strength is the main need. Clad sheets as thin as 30 gauge (0·0124 in.) are supplied, but below about 24 gauge (0·022 in.) there is real risk of trouble due either to diffusion from the core into the cladding or, with unpainted surfaces, to the polishing away of the cladding, leaving a dull patch of diffusion layer or core material. Cladding thicknesses of up to 10% of the whole have been supplied in Britain to overcome this difficulty, but some loss of strength must inevitably occur, compared with unclad material.

The missile industry has similar usage of clad sheets. In this case the main requirement is absence of even slight corrosion during storage. To achieve this many clad sheets are anodised.

The aluminium-zinc cladding on aluminium–1¼% manganese core is widely used for fuel tanks.[4] The fuels themselves are non-corrosive, but contaminated ("sump") waters are always present as a separate phase at the bottom of the tank. These may contain up to 1,000 p.p.m. dissolved solids, including 100 p.p.m. chlorides or bromides, and heavy metal compounds. While good design will enable these to be drained regularly, some pitting may occur which could cause perforation of thin unclad sheet. Lives of tanks have been increased from 3,000 hr. to more than 15,000 hr., with the tank then still being in good service condition.

Fig. 3.—Aluminium prefabricated bungalows: clad alloys were used successfully for roofing and siding.

Building—Roofing and Siding

In the years after the 1939–45 war, large quantities of surplus or scrap aluminium-copper type alloys were used for building purposes throughout the world. In this country sheet and strip had a core of the now obsolete D.T.D. 479*, with a permissible addition of up to 10% of pure aluminium. The cladding (nominally 5% on each face) was 99% min. aluminium. This was used for the roofing and external walls of all 70,000 prefabricated aluminium bungalows constructed in 1946–9.[7] Most of these remain in excellent condition, although this "stop-gap" alloy core is now known to be prone to laminar corrosion and nowadays NS3, an unclad aluminium–1¼% manganese alloy, would normally be recommended. There is possibly scope for the use of a medium strength clad alloy for roofing in a few special types of polluted atmosphere.

Screen Wires

The clad aluminium–5% magnesium alloy rod has since 1948 been steadily increasing its share of the fine wire mesh market, notably for use in corrosive conditions. The core alloy is normally of high corrosion resistance, but the extremely heavy working and the fineness of the final wires necessitates cladding to prevent disintegration by slight intercrystalline corrosion.

Beer Barrels

For many years these were made from unclad wrought aluminium-magnesium-silicon alloys, and service lives up to 17 years have been recorded.[5] Some pitting corrosion may occur due to sour beer or to improper cleaning practices, however, and an alloy clad one side (to form the inside of the barrel) was introduced in the late 1940's. The use of a clad material has since increased in barrels from the British Isles, Germany and North America. Several types of aluminium-magnesium-silicon alloy have been used for the core: one of the favourites is Alcan 55S[20] (American 53S), containing 1·1–1·4% magnesium with silicon 45–65% of the magnesium con-

* Copper 3·5–4·5%; manganese 0·4–0·7%; magnesium 0·4–1·0%.

Fig. 4.—Nameplates engraved before anodising: the aluminium - silicon alloy core anodises grey in contrast to the silver anodised aluminium background.

tent. A cladding purity of 99·8% min. is recommended. In Germany the clad alloy is occasionally anodised,[21] but this would appear to be greater protection than is really necessary.

Milk Churns

The use of clad materials for milk churns would appear unnecessary from the satisfactory use of unclad products in, for example, the Grundy churn.[24] One Italian firm, however, uses a clad material similar to that used for beer barrels : this will of course facilitate the retention of a bright interior surface, even if the cleaning technique is not always as recommended.

Kettles

The danger of perforation of kettles by domestic waters is relatively small with proper usage. The water should not be left simmering for long periods and the kettle should be emptied after each use. Where the domestic plumbing is of copper, water should be run to waste for a few seconds to avoid that which has been standing for some time in the pipes. With electric kettles the high initial cost, however, makes it worthwhile to guard against perforation by use of clad sheet which is drawn and spun to form the kettle body. In America, clad kettles have been standard practice for over ten years, the aluminium–1% zinc cladding on aluminium–1¼% manganese being widely used, but in this country a super-purity aluminium cladding is used as already discussed.[16] Originally introduced here for aggressive soft water areas, one large manufacturer now uses the clad alloy for all his electric kettles.

Heat Exchangers and Condenser Tubes

The lower strength clad alloys are utilised here for their resistance to perforation, mainly when used in aqueous solutions with *p*H 4·5–8·5. Most applications utilise tubes, and the solution liable to cause pitting is on one side only, so that the appropriate " one side only " cladding can be used. Typical examples are lube-oil coolers and natural gas compressor intercoolers and aftercoolers[22] used with many waters, including polluted sea and brackish waters. Successful service experience extends over 5 years or more in these applications, with every indication of a long life to come. Speeds of 10 ft./sec. have been tested with sea-water over a period of 18 months at the U.S. Navy Engineering Experimental Station, Annapolis, after which time the clad tubes were still in excellent service condition.[23] In many of these applications tube sheets of clad aluminium-magnesium-silicon alloys are used to maintain good overall corrosion resistance and avoid non-metallic contacts. Clad aluminium tubing is accepted for the construction of heat exchangers by the Standards of the Tubular Exchange Manufacturers' Association (T.E.M.A.) third edition 1952, and the American Society of Mechanical Engineers (A.S.M.E.) Boiler and Pressure Vessel Code, Section 8 for Unfired Pressure Vessels, 1956 edition. Longitudinally welded tubing has of course a design stress only about two-thirds that of seamless tube.

Anodised Products

The extent to which clad products may be supplied when " anodising quality " material is required in the future is not widely appreciated. Although some manufacturers appraise their customers by using trade names such as Anoclad, others take the view that the user in his application does not need to know that beauty is only skin deep ; the skin is however thick enough to allow for metal loss in normal processing.

At present the greatest demand for sheet to give a uniform response to anodising comes from the building and automobile trades. In building, the advent of curtain wall construction has opened a large market to aluminium for mullions, spandrels and infill panels, to supplement the use of the metal for window-frames, fascias, door furniture and purely decorative applications. Anodising is used in each case to retain the initial decorative appearance.[25] Claddings of 99·7% aluminium used on a core of commercial purity aluminium have been used for some years.[8] More recently aluminium-silicon alloys with 5–8% silicon cladding (usually on cores of aluminium-magnesium-silicon or of aluminium-manganese) have been developed. The anodic film on the aluminium-silicon alloy is a permanent grey, shades being developed by altering the silicon content or the heat treatment of the alloy. In America this clad product is available both as sheet and as extrusions.

The different colour after anodising of aluminium-silicon alloys and of pure aluminium has been employed for name plates (Fig. 4). In this case an aluminium–7½% silicon alloy formed the core with a 99·7% aluminium cladding. Engraving was of sufficient depth to penetrate the cladding at all points, cuts at right angles to the metal surface being employed where possible. Subsequent anodising gave a grey anodic film on the engraved letters leaving a silver anodised background.

The automobile industry in this country is now using significant quantities of anodised aluminium trim. For most purposes anodising quality, high purity (99·7–99·9%) aluminium alloyed with up to 2% magnesium gives adequate and even response to brightening and subsequent anodising. For bumpers however, this is not strong enough, and consideration is being given to a high strength alloy core with high-purity aluminium cladding.

Brazed Products

The use of brazing metal as cladding on sheet[26] instead of as separate filler rod produces a more uniform joint. It is indispensable for light gauge assemblies and for

applications with many joints, or where inspection and repair is not possible after furnace brazing. In spite of wide usage, however, there is still no British specification for those materials. The materials currently available in this country[27] have cores of aluminium–1¼% manganese or aluminium-magnesium-silicon. Cladding is with an alloy of 5% or 7½% silicon in thicknesses of 5%–20%, one or both sides. 5% usually provides adequate brazing metal for sheets 16 gauge or thicker.

The 5% silicon alloy is used for furnace and flux dip brazing of aluminium and the aluminium–1¼% manganese alloy. The 7½% silicon alloy, with its lower melting point, is used for the aluminium-magnesium-silicon alloys and for any torch brazing.

Main applications are for heat exchanger equipment of a wide variety of types, including the radiator and heater unit for Jaguar (Fig. 5) and other sports cars, refrigerator evaporators, and steam irons. This last application is of particular interest as the cladding on one side of the sheet is aluminium–7% silicon alloy (for brazing), while the other side is clad with aluminium–1% zinc for resistance to perforation by water corrosion.[28]

Conclusions

While the aircraft industry remains the leading user of clad materials, chemical engineering uses are becoming of increasing importance, particularly as long and satisfactory experience is being gained in existing applications. Potential applications in new fields, e.g. for storage of H.T.P. which is decomposed to the least extent by high purity aluminium, are under consideration. The use of cladding techniques for special products, such as sheet for anodising or brazing purposes, is likely to expand, as it is to a large extent associated with increasing use of mass production techniques.

Acknowledgments

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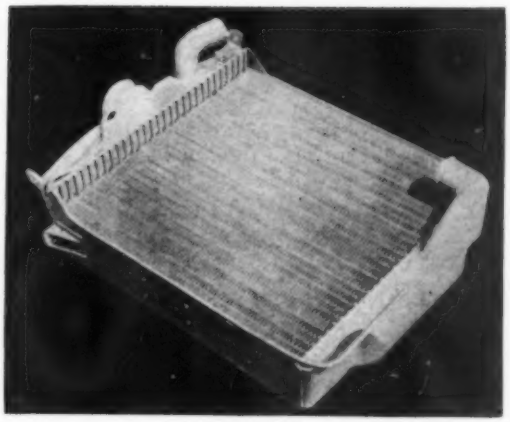

Courtesy of Marston Excelsior, Ltd

Fig. 5.—Brazed aluminium car radiator for Jaguar sports car : clad brazing sheet is used in its production.

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Films for B.A. Meeting

THE 1959 meeting of the British Association for the Advancement of Science, to be held in York from September 2nd to 9th, will include a series of scientific films, programmes compiled from recent film productions selected from all over the world, which either present scientific subjects to informed non-specialist audiences or demonstrate the use of film in scientific research.

The British Association would welcome suggestions for films (16mm. only) which might be considered suitable for screening at the York Meeting. Information about such films should include the title; whether sound or silent; black and white or coloured; running time in minutes; date of production; details of sponsor, producer and distributors; a short synopsis of content; and an indication of the type of audience for whom the film is intended. Film information sheets are available from the British Association, and details of films should be sent as soon as possible to the Visual Aids Officer, British Association for the Advancement of Science, 18 Adam Street, Adelphi, W.C.2.

Royal Society Tercentenary

ON November 28th, 1660, a group of originally minded men meeting together in the City of London decided to form themselves into a scientific society. King Charles II being informed of this, constituted himself the formal Founder, and the new society, now the premier scientific society in the world, came to be known as The Royal Society of London, or more generally "The Royal Society." The Society, whose apartments are now in Burlington House, Piccadilly, announces that it proposes to celebrate the tercentenary of its foundation from July 18th to 26th, 1960, and that a committee with Sir Cyril Hinshelwood, President of the Royal Society, as Chairman, has already begun planning for this important event in the world of science. Leading scientists from all nations are expected to attend the events, which are to include special visits to the City of London, and the Universities of Oxford and Cambridge.

The Progress of Aluminium as a Building Material

By E. H. Laithwaite, B.Sc.Tech.

The British Aluminium Co., Ltd.

Although it has only established itself as a building material since the war, aluminium has already played an important part in the development of a new style of architecture. It is more versatile than any other metal in the building field, and attention is drawn in this article to its application to cladding, curtain walling, domestic construction, and flashings and weatherings. Reference is also made to the use of colour anodising and vitreous enamelling for the production of decorative and protective finishes.

Historical Background

IT is only since the war that aluminium has come to be generally accepted as a building material, although the first applications of the metal in this field were made as long ago as 1897, only a few years after the commencement of commercial production. There are a number of examples of early building installations, in different parts of the world, perhaps the most important being the Church of San Gioacchino in Rome, the cupola roof of which was roofed in aluminium of 98·28% purity in 1897. Recent examinations have found the metal on this roof to be in excellent condition, and it has been estimated that a further life of at least 100 years is to be expected. This and other early installations used metal of a purity much lower than the commercial purity (99·0%) available today, and their successful withstanding of atmospheric conditions in different kinds of environment gives a valuable indication of the long life potential of present day material.

Following these early examples, the use of aluminium in building was somewhat spasmodic until the early 1930's, probably because of the lower cost of the more traditional metals. The advantages of the extrusion process as a means of producing sections, however, led to the development, at about this time, of the aluminium glazing bar. This was able to compete successfully with the commonly used lead clothed steel bar, and it formed one of the first applications where the combination of strength and high corrosion resistance possessed by aluminium was used to maximum advantage. Additionally, as in the case of window and curtain wall applications in later years, the production of glazing bars by extrusion allowed more complex, and more efficient, bar shapes to be designed. In this way, condensation channels, special glazing devices, and other features, were incorporated in a single section.

Courtesy of the Wey Valley Water Company

Fig. 1.—Reservoir covers in long Rigidal sheeting.

Apart from this highly successful development, most of the remaining pre-war consumption of aluminium in building went into architectural metal work of a decorative nature. A certain amount of exterior shopfitting took place, but in the main the work was internal. The benefits of anodising were of great help, and pre-war examples of anodised metalwork can still be seen in some London stores.

At the end of the war, in 1945, the aluminium industry found itself with a greatly increased production capacity, and the need to seek new outlets. The building industry was regarded as a promising potential customer, and aluminium began to be applied to a number of new uses. Projects such as the aluminium prefabricated house, formed useful testing installations, and played their part in some of the most successful later developments. Many of these houses are still in service, although originally designed for a ten-year life. In the main they utilised secondary alloy material recovered from aircraft scrap, which was readily available at the time. Although not possessing the same long life potential as virgin metal, this material has shown itself to be capable of giving very much longer service than was asked for originally.

Two of the most important developments of the early post-war period were windows and rainwater goods. Although there were a number of pre-war window installations, it was not until after the war that any degree of standardisation and quantity production took place. Nevertheless, this development has not hitherto shown the progress which has been experienced in other countries, probably because of the firmly established position of the steel window. With the recent introduction of some excellent sliding sash windows, and other casement designs which make good use of the advantages of the extrusion process for incorporating weather sealing devices, the future seems much more promising.

Rainwater goods also suffered early setbacks, due to the indifferent performance of some unsuitable materials in the years immediately following the war. The introduction of British Standards did much to offset this, and this application is now firmly established and steadily developing.

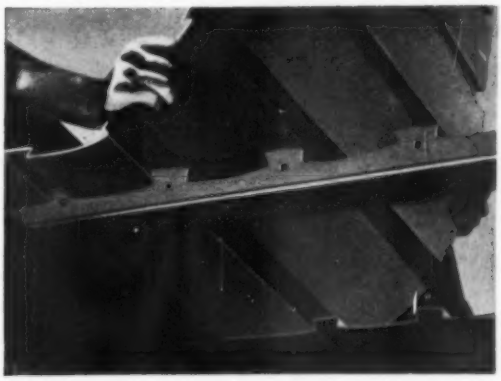
Cladding

It is, however, in the field of the cladding of industrial buildings that aluminium, usually in the form of corrugated sheet, has scored its biggest success. Although in the upper price bracket of available roofing materials, the clean appearance and remarkable durability of aluminium under the most rigorous industrial atmospheric conditions contributes to its ever-widening popularity, while its light weight and availability in sheets of great length makes fixing a rapid operation which appeals to building owners and fixing contractors alike. Large areas of aluminium roofing and wall cladding are now to be found in dock and harbour installations, and on gas works, power stations, paper mills and all manner of smaller industrial buildings.

Compared with other forms of metal corrugated sheeting on the market, aluminium is alone in combining strength and rigidity with an integral protective skin, i.e., the tough, transparent surface layer of oxide. This has the marked advantage of being self sealing in the event of local damage, whereas a protected steel sheet will tend to rust rapidly once the protective envelope is pierced in any way. In addition, one must consider the flame spreading properties of bitumen-containing protective envelopes. Aluminium is one of the materials classified as having a low rate of flame spread under B.S. 476.

The use of very long corrugated sheets is, of course, much more practicable with aluminium than with the heavier steel sheeting, and during the last two years, sheets of 35 ft. or more in length have become available. The British Aluminium Co., Ltd., offer both their Rigidal Trough T sheeting and the conventional 3 in. pitch profile in these lengths, and samples of both were displayed at the November, 1957, Building Exhibition at Olympia. A typical application of long sheets is the barrel vault roofing, 38 ft. 6 in. span, recently installed at a small rural district water storage reservoir at Hindhead, Surrey (Fig. 1). Long sheets, by avoiding end laps, economise on both material and labour, and being laid continuously over several purlin spans, provide better rigidity and load bearing capacity. Wide sheets also have the advantage of economy, and the standard 8/3 in., 2 ft. 2 in. wide, corrugated sheet is rarely called for now that sheets double the width are available in the easily handled light metal.

Considerable development has taken place in recent years in other forms of aluminium cladding, generally in the direction of providing a more attractive appearance by using concealed fixings, or exposed fixings less unsightly than hookbolt threads and nuts. Several proprietary systems are now on the market, one example being Fural, a neat and efficient roof or wall covering laid by rolling out lengths of transversely ribbed strip so that the dovetailed ribs lock into position over a correspondingly shaped fixing member (see Fig. 2). It was this system which came in for much unfair publicity at the time of the disastrous gale damage at Hatfield New Town in November, 1957. The phrase "aluminium roofs blown off" appeared in the front page headlines



Courtesy of Fural, Ltd.

Fig. 2.—Fixing Fural roofing.

of several national newspapers at the time, but little prominence was given to the finding of the official enquiry some months later. This completely exonerated the metal roof covering from blame, and placed the responsibility firmly on the inadequate anchoring of the timber understructure.

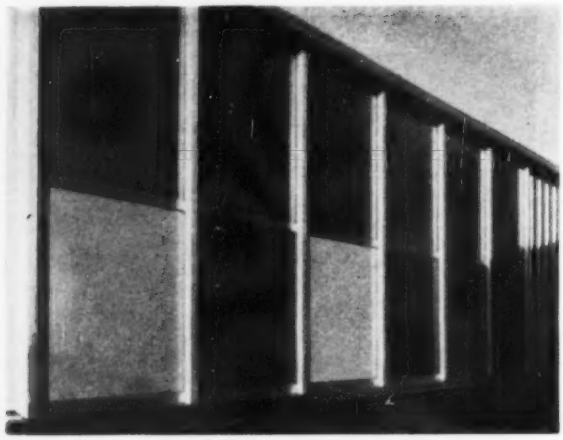
With the coming into force of the Thermal Insulation of Industrial Buildings Act, 1958, there will naturally be a demand for insulated forms of roof and wall cladding. The aluminium industry has not been slow to seize the opportunity presented, a typical development being the introduction of "sandwich" walling, involving two skins of corrugated aluminium sheeting with a core of insulating material, such as resin-bonded fibreglass, between. By this straightforward use of standard materials, it is possible to erect, on site, a wall with a U-value of 0·18 or better. One method of erection incorporates a welded stud, finished off with a neat and inconspicuous aluminium dome cap as the only visible evidence of the fixings.

These, and other systems currently under development, provide evidence of the value which architects and engineers place upon aluminium as a cladding for modern industrial buildings.

Curtain Walling

One of the most significant post-war developments in architecture is that of the metal and glass system of curtain walling. Pioneered in the United States, this method of enclosing buildings with thin lightweight walls, literally hung from the frame, quickly found favour in other parts of the world. In the United Kingdom, aluminium curtain walls have been used on office buildings and schools, and in Switzerland and Germany particularly, some very attractive buildings have been completed in this way.

In its simplest form, the metal curtain wall consists of mullion sections spanning from floor to floor, in continuous lines between roof and ground, with alternating clear glass and metal or some other form of infill panels between. Extruded aluminium sections are an obvious choice for curtain wall mullions, as glazing stops and other features may be incorporated in the one section, and the metal's great resistance to atmospheric attack obviates the necessity for any applied protective coating. In other words, the mullion is at one and the same time, functional, decorative, and durable. Frequently, of course, an architect will specify anodising, thereby



Courtesy of Freeman, Morrison, Ltd.

Fig. 3.—Split mullion curtain walling.

considerably enhancing the appearance of the mullion, and simplifying the problem of maintenance.

From the point of view of erection also, aluminium is ideally suited to curtain wall construction, not only because of its light weight and ease of handling, but also on account of the fact that special fixing devices may be incorporated in the profile of the extruded section itself. An example of this is the split mullion method of curtain wall construction, which enables large size components to be shop fabricated, complete with glazing and infill panels, and rapidly erected, unit by unit, in much the same way as tongued and grooved boarding goes together. The joint in the mullion, besides making possible erection by component, allows for free movement of the wall under normal expansion and contraction. The section of wall illustrated in Fig. 3 is an example of a split mullion curtain wall; it is a newly designed British system, incorporating Neoprene extrusions for weather sealing.

Although aluminium curtain walling is often more expensive than traditional masonry walling, it has proved popular because of its speed of erection, because it does not take up much valuable floor space, and, probably most important, because of the possibilities it offers for colour treatment.

Finishes

At this juncture, it is perhaps appropriate to consider the progress made in recent years in providing coloured finishes on aluminium. Colour anodising is by no means new, and there are many long-standing examples in existence in the form of interior metal work in stores, hotels, restaurants and similar buildings. This attractive finish has also been employed commercially for many years in the manufacture of domestic metalware, such as trays, tumblers, cocktail shakers and similar articles. Until recent years, however, colour anodising could not be used successfully in external applications, owing to the lack of suitable light fast dyes. There is now a limited range of such dyes available, and a colour chart recently issued by The Aluminium Development Association includes a yellow, a green, a blue and a black.

Variations of these colours may be obtained by applying them to a 5% silicon alloy of aluminium, which, on anodising, takes on an appreciably darker shade of grey than occurs on the pure metal and other alloys. Clear anodised 5% silicon alloy is often used alone because of its attractive medium grey finish, but when coloured films are used, they appear proportionally darker.

Colour anodised infill panels in curtain walls have been used to considerable effect on a number of recent buildings, in the United States particularly, and in European countries, including Britain, also. One of the most impressive is the silver and blue facade of the Pennsylvania State Office building in Pittsburgh (see Fig. 4).

A new form of finish now being applied to aluminium is vitreous (porcelain) enamelling. Again this has undergone its greatest development in the United States, where at least one company has specialised in it for some twelve years. Extensive trials have been carried out, with such success that this finish, too, is being employed in curtain wall installations on buildings of skyscraper proportions. In Fig. 5, the continuous lines of the mullion covers of the all-aluminium wall are finished in white vitreous enamel.

The range of available colours in vitreous enamel is naturally very much wider than that applying to anodising, and different degrees of gloss may be obtained. The type of frit employed has a fusing temperature of about 550° C., very much lower than that used for enamelling steel. At this temperature, aluminium and aluminium alloys are fully annealed, and this must be taken into account. Heat treatable alloys, air quenched after enamelling, are used where strength is important, but excellent results are also obtained on 1¼% manganese alloy (B.S. 1470–NS3). It is claimed that the addition of the enamel coating stiffens the product and compensates to some extent for the loss of strength through annealing.

The advantages of enamelled aluminium over enam-

Fig. 4.—The Pennsylvania State Office in Pittsburgh has colour anodised infill panels.

elled steel are the absence of chipping—allowing drilling after enamelling and cutting of edges—and, the fact that in the event of local damage, the natural resistance to atmospheric attack of the aluminium prevents any spreading by rusting. In addition, the light weight of aluminium can be a distinct advantage where the building up of large sandwich panels is required.

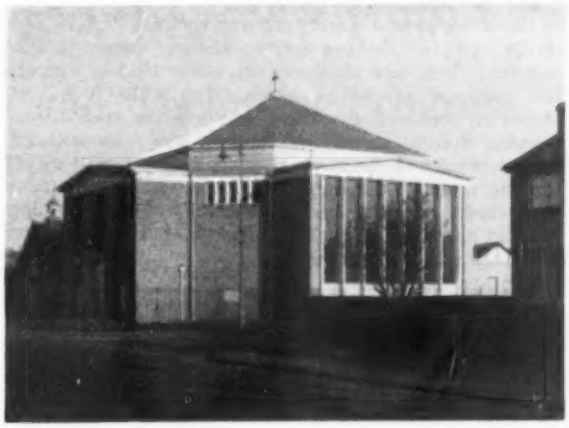
Interest in vitreous enamelling of aluminium is rapidly increasing in this country. Several firms are installing new furnaces, and The Vitreous Enamel Development Council are paying particular attention to the architectural field.

Domestic Construction

It will have been noticed that frequent reference has been made to the United States of America in describing recent developments of aluminium in architecture and building. This is inevitable in any survey such as the one this article is intended to cover. No one will deny that in this country our attitude towards new materials and methods in building is a very cautious one. In a younger country like America, it is to be expected that architects and owners will be more adventurous, and indeed it seems sometimes that there is considerable competition to be the first user when a new material is announced. Although aluminium was used to roof a church over sixty years ago, it is still a new building material, and it seems it will remain so, as far as this country is concerned, until that particular church roof is two hundred years old, and other roofs nearer home well on the way towards that figure.

Nevertheless, so great has been the increase in the use of aluminium in building in the U.S.A. during the last few years, that inevitably the same pattern will be repeated here. There has always been a natural interchange of the best ideas between countries, more so nowadays on account of faster travel, and the influence

Fig. 5.—The Tishman Building on Fifth Avenue, New York, has part of its aluminium wall vitreous enamelled.



Architects: Thos. F. Ford & Partners.

The roof of St. Peter's Church, Bexleyheath, is covered with Super Purity aluminium.

of contemporary American architecture is clearly to be seen in Europe. It has been stated that over 20% of all the aluminium produced in America goes into the building industry. In no European country—and Switzerland is the leader, not Britain—has the figure yet reached 10%, but many people anticipate that in time the percentage consumption here will draw much nearer to that of America.

Domestic construction forms a very large part of the building activity in any country, and it is interesting to note that the American aluminium producers have recently concentrated their efforts on this market. It can, of course, be argued that the traditional American frame house lends itself better to the introduction of a material like aluminium than our own masonry built structures, but there are signs which suggest that the advantages of lighter, more easily erected buildings, are not being entirely ignored. There is, in fact, a growing conviction that it is time we paid more attention to the provision of year-round interior comfort, and less to that of exterior solidity in our houses. Light-weight, well insulated, factory built components could play a significant part in achieving this, and in reducing building time and costs, and aluminium has properties which commend it very strongly in this kind of application.

In many houses now being erected in the United States, aluminium is employed in the following applications :—

Windows, shingles, gutters, downspouts, flashings, soffits, sliding doors, door furniture, vent flues and chimneys, thresholds, weatherstripping, shutters, siding, screen doors (external), storm windows, awnings, ventilators, handrails, ventilation ducting, thermal insulation, wall tiles, grilles, and bathroom screens and frames.

One great advantage becomes obvious immediately to the householder—the avoidance of all external maintenance. The window frames and doors require no painting, and the siding and shutters are stove enamelled. The first cost is little or nothing above that of the same house in conventional materials.

Flashings and Weatherings

It was as a roof weathering that aluminium was first used in building, and although its relatively high price in the first half of this century restricted development

in this field, it has become, during the last decade, one of the accepted flashing and weathering metals in this country. It is now cheaper than either lead or copper, but possesses properties which often make it a first choice on technical grounds alone. In the case of one London church recently, aluminium was recommended by independent experts as being the most suitable metal for the roof, in the particular industrial environment concerned. In another case, involving a church building of great historical value, a well known architect specified aluminium because he liked the colour and appearance of the weathered metal.

It is generally because of its mechanical properties, however, that aluminium is preferred as a roof metal. Pure aluminium, and particularly super purity metal (99·99%), is capable of considerable cold working, and plumbers and specialist roof workers find it can easily be laid by traditional techniques. Its lightness, combined with adequate tensile strength, ensures that creep cannot occur, even on the steepest roof slopes. Unlike some of its rival roof metals, aluminium can be laid in long lengths, a practice which makes it particularly suitable for the wide, low pitched roofs often seen in contemporary buildings. Panels some 28 ft. long will shortly be laid on an industrial building in Scotland, jointed by means of standing seams, and fixed by special sliding clips which take up expansion movement. This system is new to this country, but it has been used with considerable success in Switzerland for many years.

The traditionally laid metal roof weathering has much to be said for it, because it provides protection of the highest efficiency, with every joint formed by hand so as to provide absolute weather tightness. In addition, aesthetically, a properly laid roof can add much to the appearance of a building. There are now many such roofs in aluminium, weathered to a pleasing grey colour not unlike that of the more traditional lead, which provide evidence of the successful development of aluminium in this field. Among them are many churches, and many schools and colleges (see Fig. 6).

As a flashing metal, aluminium is to be seen on housing schemes in all parts of the country. This utilitarian application is not one which consumes enormous quantities of aluminium, but, perhaps more than any other single application, it has played a very important part in the development of aluminium as a building material, by bringing the metal to the notice of the smaller firms of builders and plumbers. It is not easy for the average tradesman to appreciate that the same metal from which the modern airplane is built, can be used to flash a chimney or line a valley gutter. To most people, aluminium is aluminium, one metal, and they are quite unaware of the wide range of differing properties which the various alloys and specifications make available. There is therefore much work to be done in educating the user, to ensure that he obtains metal of the correct specification appropriate to the job he has in hand.

Associated with this is the business of distribution. Few ironmongers or builders' merchants carry stocks of aluminium, yet it is a material particularly suitable for use by the jobbing builder, or even by the "do-it-yourself" handyman. This is a potential market to which the aluminium industry will be paying much attention in years to come.

Summary

Recent years have seen aluminium firmly established in many departments of building construction. The possibilities for further development are considerable, and the next ten years might well see the tonnage of metal absorbed by the building industry doubled in size. Aluminium has already played a significant part in the development of a new style of architecture, while at the same time fulfilling a useful function in replacing more traditional metals in conventional forms of construction. There is no other metal which can compete in so many different fields of application in building.

Acknowledgment

With the exception of Fig. 2, all illustrations are by courtesy of The British Aluminium Co., Ltd.

Nu-way School of Oil Firing

Nu-way Heating Plants Ltd., announce that, following a complete re-organisation of its training facilities, Mr. H. W. Burbery, formerly the company's Installation and Service Manager, has been appointed Principal of the Nu-way School of Oil Firing. Mr. Burbery is a veteran of the oil burner industry, having installed American automatic burners in Birmingham as long ago as 1923. In the course of his long career, he has been responsible for the installation of many types of domestic, commercial and industrial oil-firing equipment.

The Nu-way School of Oil Firing was founded in 1952 to provide elementary instruction on the installation and servicing of oil burners for fitters employed by accredited Nu-way dealers, and in the past six years more than 800 engineers have taken this one week course. During the same period the School has been greatly expanded, so that courses of varying duration are now run, not only for engineers from all sections of the heating trade, but also for oil company representatives, boilerhouse superintendents, industrial furnace builders, and technical staff from manufacturers of oil-fired heating equipment.

In addition, specialised courses are run to meet the particular needs of certain large organisations, a recent example being the series run to train the district engineers and chief operators of A.B.C. Cinemas, Ltd., in connection with the very large oil firing conversion programme on which that company is now engaged. Details of the regular courses, which are free, may be obtained from the Bursar, Nu-way School of Oil Firing, Vines Lane, Droitwich.

The Institution of Plant Engineers

With effect from January 16th, Incorporated Plant Engineers has changed its name to The Institution of Plant Engineers. Since the Institution is a company limited by guarantee, any change in title needs the sanction of the Board of Trade and where the desired name includes both the words "Institution" and "Engineers," such sanction is by no means automatically given. Futhermore, the Board's requirements are particularly stringent, when a body holds (as the Institution does) a licence to dispense with the word "Limited." Essentially, the Board needs to be satisfied that the grant of the title will not damage the status and standards of the engineering profession as a whole or those of the established professional institutions. That permission has been granted is, in these circumstances, a gratifying recognition of the work of the Institution.

Aluminium and its Alloys in 1958

Some Aspects of Research and Technical Progress Reported

By E. Elliott, A.Met., F.I.M.

Chief Metallurgist, The Aluminium Development Association

Attention is drawn to work published in this country and the U.S.A., reporting research and technical progress in the various aspects of the metallurgy of aluminium and its alloys, including extraction, founding, fabrication, constitution, properties and standardisation. Reference is also made to interesting applications of these materials.

THE year 1958 marked the three-hundredth anniversary of the accession to the English throne of its most illustrious occupant, and it fell early in the second Elizabethan age. The era of Raleigh and Drake was a period of the pushing forward of frontiers, both geographically and those of knowledge. Science and technology now stand upon a peak from which the next advances will probably be beyond our wildest surmises, but they are not silent; the flood of papers, articles and books continues, to the delight and despair of the technical reading public, who see themselves more and more unable to keep afloat in the ocean of information.

Production

The early months of 1958 brought news of the initiation of aluminium production at Baie Comeau[1] on the north shore of the St. Lawrence River in Canada, less than 20 months after work was commenced on clearing the site. This first stage of operations will produce 40,000 tons of metal a year, and eventually the total capacity will be four times this figure. Confidence in the future during a period of surplus virgin aluminium ingot is also shown by other developments in Canada, particularly the work at Chute-des-Passes,[2] also in Quebec, where a new reservoir will provide sufficient water power to increase the output in that area of the major Canadian producer to 3·58 million horsepower by 1960.

France has always been prominent in the aluminium field, and Starratt[3] recalls that the principal ore of the metal owes its name to "a sleepy little village on the rocky cliffs overlooking the old Roman City of Arles." He presents a general survey of the present French aluminium industry, including reference to developments in production in the Cameroons and in Guinea. Baudart[4] has also briefly reviewed French contributions to aluminium technology, as regards both production and working. A particularly impressive point that he notes is that, while in 1938 some 22,000 kWh. of electrical energy was needed to produce one (short) ton of aluminium, this had been reduced in French pot-rooms to 17,000 kWh. by 1956, and is now as low as 16,000 in the most efficient plant.

There are large deposits of bauxite in Jugoslavia,[5] but in 1957 only 18,000 tons of aluminium were produced. This will be increased to 100,000 tons per year by 1964, as a result of the completion of the works at Titograd and Kidricevo. Hungarian bauxite is well-known for its high quality, and new mines are to be sunk[6] in order to increase production both of the ore and of the metal, the latter to 45,000 tons per year by 1960. Gallium is to be made as a by-product, and iron oxide extracted from red mud, while 600 tons of synthetic cryolite per annum is also envisaged.

Johnson[7] has discussed technological improvements made by metallurgical engineers in the Hall-Héroult process, and he considers that there is evidence that the lowering of current densities can no longer reduce production costs. In an interesting table he compares ideal requirements of material and energy with those at present used in practice; the room for improvement is obviously limited, except in electric power. The theory of the electrolysis of aluminium from cryolite melts is complex, and Stokes[8] has surveyed critically the literature on the subject. He concludes that present data are inadequate for quantitative resolution of the theories advanced.

The transmutation of base metals into gold may be a possibility in these atomic days, but it is still not a regular industrial process. Scrap aluminium alloys, especially in large piles in scrap dealers' yards, do not seem a particularly promising raw material, so that those companies who produce from them ingots to British Standard specifications may be regarded as the modern alchemists, except that they are successful in their major task. The history of one British company[9] specialising in this field has been recounted, on the occasion of its silver jubilee; its melting capacity has increased in the quarter-century from 2 to 160 tons.

Melting and Casting

One of the important features of modern technology is that contributions to its advance come from sources which in the past were not available, as, for instance, many of the countries of Asia. There is, of course, traffic in both directions, and Fletcher[10] has provided for a Symposium in India an interesting paper summarising present-day techniques in the aluminium alloy foundry, covering all the commonly used methods of making castings. Fletcher[11] has also described the works of the Northern Aluminium Co., Ltd., at Birmingham, with full details of melting equipment, sand and gravity die foundries, and heat-treatment facilities. Mention is also made of the forge which forms part of the same factory, and has pneumatic hammers,

drop stamps, and hydraulic presses ranging up to 4,000 tons. This account was written because the works was one of those visited by those attending the Golden Jubilee Autumn Meeting of the Institute of Metals; another factory in the itinerary was that of the Wolverhampton Die Casting Co., Ltd., which has also been described.[12] Twenty pressure die casting machines are in use with aluminium alloy, the largest accommodating dies up to 34 in. between tie bars, and locking pressures range from 300–600 tons. The Spring Meeting of the Institute was also accompanied by many works visits, and Payne[13] has taken readers on a tour of inspection of the Charlton foundries of J. Stone & Co., Ltd., whose activities include the production of aluminium alloy castings by all the common methods; sand castings up to 2 tons in weight are made.

Colwell,[14] reviewing from an American standpoint pressure die casting in other countries, enables us to go part way towards obtaining that gift for which Burns sighed, and it is interesting to note that he considers that Europe (with which he includes England), has taken advantage of American techniques, although its total production of aluminium alloy pressure die castings is well under half that of its transatlantic cousin. An English company has developed what might be called pressure die cast slush casting.[15] Special equipment, automatically controlled, injects metal into a mould, and, after a predetermined period, sucks out that still remaining molten in the middle of the casting. Thus the best part of the casting is retained, and considerable weight saving achieved by removal of the centre. Die wear is also reduced, and production speeded up. The method is applicable to aluminium alloys as well as to other metals, and to even more exciting tasks such as making hollow chocolate Easter eggs.

Many factors work against the foundryman in his endeavour to obtain accurate reproducibility of dimensions in castings, and for very close tolerances he must have recourse to precision investment methods. While the process by which the golden calf was made is still in use, with wax as the investment, a more recent technique is that based on frozen mercury, and it has been described in detail;[16,17] tolerances of the order of $\pm 0{\cdot}003$ in./in. are claimed for most alloys, and the process is particularly valuable in wave guide production.

The modification of aluminium-silicon alloys continues to fascinate investigators, and Ghosh and Kondic[18,19] have discussed the results of their work on microstructures in aluminium–12% silicon alloy in the light of current theories. They conclude that the nucleation of the Si-phase is not the controlling factor in coarseness, but that the suppression of grain growth resulting from modification or rapid cooling is the main phenomenon. Cell formation is demonstrated in both modified and unmodified structures, so that this is not one of the basic differences between the two. Working with aluminium–7·5% silicon alloy, and using a number of techniques, including autoradiography and electron microscopy, Plumb and Lewis[20] propose a theory of modification more closely related to the older hypothesis that the agent retards nucleation of eutectic silicon, so that solidification occurs at a temperature well below the true freezing point of the alloy, where individual silicon crystals cannot grow to a large size. All this perhaps calls to mind young Omar coming out of the door that he used as an entrance; the eager frequenting is, however, well worthwhile, despite the lack of unanimity between the sages.

The design of aluminium alloy castings is an art, but to practise it much technological knowledge and experience is necessary. Broadbent[21] has summarised the many aspects of economic design in a most practical way. This paper is to some extent controversial, as for example when the author states that where steel would need painting, so would light alloy; again, not all would agree with his assigning to alloy LM10-W a maximum working temperature as high as 200° C. That certain users consider the right aluminium casting alloys to be highly corrosion-resistant is shown by the production of small boat fittings[22] as pressure die castings in alloy LM6-M. The principal foundry interest of this development is that the manufacturers, by keeping to simple dies, are able to use the pressure die casting method for quantities well below those usually considered sufficient to render the process economic. A well-known manufacturer of steam irons is making sole-plates[23] as pressure-die castings in an aluminium–7½% copper alloy, and details have been given of the foundry technique. The 1 kW. heater is cast into the sole-plate, and a two-cavity die is used.

Sand and gravity die cast doors for rail vehicles are increasing in popularity, and an account[24] has appeared of their production in alloy LM6-M. The large-scale pressure die casting of cylinder blocks for motor-car engines is similar to the despatch of a rocket vehicle round the moon, in that it is expected to happen in the near future. An American company[25] is engaged in a similar activity, having in operation a production line for pressure die cast V-4 blocks for an outboard motor, using an alloy of type similar to LM20-M. Hypereutectic aluminium-silicon alloys, usually with a nickel addition, have their protagonists as cylinder block materials, and it is therefore interesting to read Kessler's[26] account of long experience with them as piston alloys, including the very high silicon variety. He draws attention to difficulties in grain refinement, with which, however, considerable progress has been made.

There is, we are told, no merit in mere size. Nevertheless, no one could fail to feel pride in the production of the largest aluminium alloy casting[27] ever made, especially when this is a hatch cover complying with Lloyd's requirements, weighing 7,500 lb., and nearly 19 ft. square. Alloy LM6-M was used, and 4¼ tons were melted, degassed and modified by sodium. Although still some way from these dimensions, pressure die castings are increasing in size and a British company has recently acquired a machine[28] capable of taking 40 lb. of aluminium alloy, with a clamping force of 30 to 1,500 tons. Similar—and even larger—machines are described by Bauer,[29] but they are all in the U.S.A. He considers the particular difficulties of operating such machines, one of which is automatic ladling, which can introduce breakdowns. Which shows how efficient the human hand and arm can be, despite the advantages of automation.

McDonald, Dore and Peterson,[30] noting the attention devoted to plastic refractories for lining aluminium melting furnaces, have investigated their suitability for contact with the molten metal. Low temperature firing gives good strength, but poor resistance to metal penetration, and the authors conclude that plastic refractories are not completely suitable for use below the metal line. The advantages of hot-top pouring in continuous and semi-continuous casting have been set

forth by Jones and Kondic;[31] they are principally improvements in surface quality of ingot, both as regards absence of surface dross and reduction in exudations.

One of the main post-war advances in the quality of aluminium alloys, particularly in those of high strength, has been in the reduction of gas content, and Ransley[32] and his colleagues have put an important weapon in the metallurgist's hands with their instrument for direct measurement of hydrogen in molten aluminium alloys. Milbourn and Gidley[33] have described the control analysis of aluminium alloys by direct reading spectrographic methods, the adoption of which has resulted in reduction of staff engaged on analysis, accompanied by greater accuracy of control of alloying constituents, and the virtual elimination of casts outside specification composition.

Working

The Jubilee Meetings of the Institute of Metals have already been mentioned; the visits associated with them resulted in the publication of many very informative descriptions of works producing semi-fabricated forms in aluminium and its alloys. These accounts are highly summarised, and well illustrated; they cover the Kitts Green Works of James Booth & Co., Ltd.,[34] Birmetals, Ltd.,[35] at Woodgate, the Banbury factory of the Northern Aluminium Co., Ltd.,[36] and Enfield Rolling Mills, Ltd.,[37] at Brimsdown. Throughout these articles the impression is gained of increase in efficiency and in size of equipment and of products. Such advances demand close technical control, so that it is fitting that visits were also paid to Aluminium Laboratories, Ltd.,[38] at Banbury, and the Research Laboratories of the British Aluminium Co., Ltd.,[39] at Gerrards Cross. The fields covered by both these well-known research organisations are vast, and stretch from fundamental investigations of alloy systems to the final finishing of wrought and cast products.

In this atmosphere of jubilee, it is apposite that a company celebrating its own golden anniversary in 1959 should already have well advanced a considerable modernisation programme; Aluminium Corporation, Ltd.,[40] once a producer of virgin metal, now a well-known sheet roller in North Wales, will shortly have a new 2-high reversing hot mill with associated equipment. In another part of the principality (if Monmouth may be included in that country), the installation of large equipment for plate manufacture—heat-treatment furnaces, an enormous stretcher, a special plate saw, and so on—attracted attention in many fields,[41-43] particularly since attainment of great widths involves welding. This stage is, however, temporary, since further capital investment is to provide a hot mill able to roll plate up to 12 ft. wide. Still concentrating on size, but turning now to Scotland, it must be recorded that corrugated aluminium sheet[44] is now produced up to 35 ft. long, or even longer by special arrangement, at a corrugating speed of 450 ft./min.

Green[45] has described the modern production of aluminium foil, and its conversion, this last term embracing coating and laminating. He reminds readers that the thickness of the thinner foils commonly made is less than one-tenth of that of the average human hair, which is a tribute to the technical control of the rolling operation; the functions of the laboratory[46] in this field have also been listed. One of the main applications of metals is in the shaping of other metals, and Rodgers[47] has given advice on the correct steels to use for the various parts of an extrusion press, namely container, liner holder, liner, ram, mandrel and dies. This is a detailed and valuable account, bringing together much important information.

Use of large forgings and thick plate, particularly in aircraft production, has stimulated interest in non-destructive methods of flaw detection, particularly by ultrasonic means. Applied to cast billets, such technique can ensure that no material containing defects likely to render useless the final products is forged or rolled; the forging or plate can also be examined, in order to demonstrate its soundness before the aircraft manufacturer begins his part of the work that eventually results in a safe aircraft. The development of the necessary equipment for this mode of inspection has been described by Claydon,[48] including both hand-operated and automatic units. He stresses the importance, for most comprehensive results, of designing the installation for its particular purpose. Harris and Crowther[49] have given an account of their experience with ultrasonic testing, and have shown how they have improved the quality of plate, extrusions and forgings in high strength alloys. This paper is something of a *tour de force*, the illustrations of defects located by ultrasonic means being particularly interesting.

The working of aluminium and its alloys by the final fabricator often involves a considerable amount of bending, and the publication by the Aluminium Development Association of an Information Bulletin[50] on the subject is therefore to be welcomed. It covers the bending of sheet and strip, plate, bars and sections, and tube, and includes the safe radii to which the various alloys may be formed. Barlow[51] has also devoted attention to problems involved in bending tubes, and in addition to giving tables of bend radii he follows a discussion of springback with a table by means of which it may be calculated for various alloys and tempers. According to Tilsley and Howard,[52] blanking and piercing are probably more widely used than any other press-working operation; in a general discussion of recent developments they describe the finish blanking of aluminium. By keeping clearance between punch and die to as little as 0·001 in. per side, impact extrusion slugs may be made with a very smooth finish on their periphery. To get the best of both worlds is a common ambition, but to obtain hardness in both the worked and unworked areas of deep-drawn products has hitherto been beyond attainment. It may now be done by the use of differentially annealed blanks,[53] which, in contrast to chocolate creams, have soft outsides and hard centres.

Mark Antony would have been a popular man with sheet metal workers engaged in deep drawing; indeed, they would gladly make permanent the loan of their auricular appendages. Developments over the past few years have, however, made caring far less of a problem, and Thorley and Tucker[54] have described the very close control of fabricating conditions that has led to this improvement. Flow-turning is now well established in this country for the production of vessels with thick bases and thin sides, and also where sides of varying thickness are required; a typical installation[55] has been noted. The working of aluminium foil, although increasingly practised, is seldom described in detail, and an account[56] of the bonding of foil 0·005 in. thick is therefore the more interesting. Twenty-eight U-bends per minute are made, and the folded foil forms part of a cooler

for a ciné projector. The principal product resulting from the high quality aluminium alloy plate mentioned above is, of course, machining swarf, and to make integrally stiffened structures from the material high-speed machining is essential. Routing is a favoured method, and a large installation[57] has been described.

Another Institute of Metals visit was to the new factory of a company which was one of the earliest to carry out in aluminium the fabrication of chemical vessels, and the plant of the APV Co., Ltd., and type of work undertaken have been discussed and illustrated by Parkes.[58] Aluminium is particularly suitable for handling high test peroxide, as it does not catalyse the breakdown of the chemical. Much of the equipment for dealing with this essential adjunct to rocketry is being made in the pure metal to very high standards, as is shown by an account of the work of Saunders Roe (Anglesey), Ltd.[59] in this field.

Mention must again be made of METALLURGIA'S annual review[60] of furnaces for heat treatment and heating for working. This comprehensive and well illustrated feature includes a furnace capable of heating 10 tons of aluminium plate for solution treatment, or twice that amount for precipitation treatment, and an induction heater for aluminium extrusion billets.

Joining

Most industrial processes depend at some stage upon the joining together of parts to make a whole, and the literature dealing with the various techniques is correspondingly voluminous. Burgess[61] has summarised recent progress in joining aluminium and its alloys, concentrating principally on welding, but with some reference to soldering and brazing. He notes that thin foil and plate as thick as 6 in. can now be readily joined, and indeed there are no practical limits to size and thickness in modern welding. Recent developments in welding have also been surveyed by Humberstone,[62] dealing with all metals, and he emphasises the rapid growth of the technique over the past few years, and the contribution that it has made to cost reduction and flexibility of design; one quoted example of this last is the use of welded aluminium in superstructures of U.S. naval vessels. For the butt and fillet welding of aluminium alloy plate, particularly in shipbuilding, Tomlinson and Blewett[63] have designed an inert-gas metal-arc equipment which is self-guiding. The welding head runs on tracks, and is kept in line by a suitable arrangement of guide wheels. Tomlinson and Slater[64] describe the automatic welding by consumable electrode methods of 99·5% aluminium and aluminium-magnesium alloy plate for the construction of chemical vessels, and discuss the effect on the weld of such variables as inclination of welding head, arc voltage and current, welding speed and edge preparation.

The inert-gas metal-arc welding of thick aluminium plate, using high currents to avoid the need for preheating, has in the past suffered from the occurrence of "puckering", an irregular weld bead profile associated with oxidation. After investigating the effects of many variables, Smith and Houldcroft[65, 66] came to the conclusion that air entrainment in front of the weld pool is the main cause of the trouble, and by the use of a supplementary shielding nozzle they were able to weld at high speeds with currents greater than 500 amp. Needham and Smith[67] have made weld tests on pure aluminium by self-adjusting-arc at constant voltage with increasing wire feed rates, and shown that there are three distinct ranges, namely sub-threshold, where metal transfer is intermittent; normal, with rapid transfer of small droplets; and defective, with turbulent arc and large internal voids. Only the middle stage is suitable for welding.

Porosity in welds continues to receive the attention of investigators, and Collins[68] has shown that it is more often caused by atmospheric contamination of the shielding gas than by hydrogen in the parent metal. This author states that in consumable electrode welds less porosity is experienced in aluminium-magnesium than aluminium-magnesium-silicon alloys, and that hydrogen pick-up can be minimised by using a helium-argon mixture as the shielding gas. He considers chlorine additions to have disadvantages that make them undesirable for most applications. This is not the view of Kasen and Pfluger,[69] who demonstrate that the flow of chlorine into the arc area at rates of from 3 to 20 cu. cm./min. counteracts the deleterious effects in inert-gas metal-arc welding of aluminium-magnesium alloys of hydrogen, propane, water vapour, and oxygen, as well as contaminated filler wires. Radiographically sound welds are produced, and it is suggested that by making filler wire quality less critical, welding costs might be substantially reduced. Hull and Adams[70] have investigated the causes of porosity in metal-arc welds in aluminium-magnesium-silicon alloys, and they conclude that, although moisture may be removed from electrodes by baking, any significant improvement in weld soundness depends on the elimination of water of crystallisation from coatings and the prevention of corrosion of the core wire by surface protection or control of storage conditions. Indeed, the loathing of welders for water would be difficult to match in any other class of individuals south of the border.

The development of filler alloys for the welding of aluminium-copper-magnesium heat treatable wrought alloys has been brought to a successful termination, and Houldcroft[71] has described the extensive research which led to the conclusion that the optimum composition was 7% copper, 3% silicon, and about 1% magnesium. With this filler, failure occurs on testing at the edge of the weld bead, although it is suggested that precipitation treatment may transfer this to the plate material. In collaboration with Fidgeon, Houldcroft[72] has subsequently taken this investigation further, and shown that with aluminium-copper-magnesium alloys, the filler mentioned above, but with 1·5% magnesium, provides a weld bead with hardness greater than that of fully heat treated parent material, by precipitation treatment after welding. There is also a possibility of developing for aluminium-zinc-magnesium-copper alloys a filler which will age satisfactorily, though slowly, at room temperature. Burch[73] has also reported work on the welding of heat treated aluminium alloys of the aluminium-magnesium-silicon-copper-chromium type (similar to H20), in the solution treated condition. He has established that $\frac{1}{4}$ in. from the weld a temperature of 370° C. is attained, regardless of welding speed, but the intensity of over-ageing depends on the length of time that this zone is in the range 300°–370° C., which is inversely proportional to the welding speed. With rapid welding, using the aluminium–5% silicon filler rod, precipitation treatment after welding gave joints closely approaching the strength of the fully heat treated plate material. In a general survey of the properties of welds in aluminium

alloys, Dickerson[74] confirms this finding, and adds that when welding the fully heat treated alloy, better ductilities are obtained with aluminium–3¼% magnesium filler than with aluminium–5% silicon. This article also gives a useful list of the bodies that have published, in America, rules governing design with aluminium alloys in various fields.

Adams[75] has determined the effects of porosity and weld shape on the tensile strength of metal-arc welds in an aluminium-magnesium-silicon-manganese alloy in plate form (HP30), comparing the results with those obtained with inert-gas-shielded metal-arc welds. The metal-arc welds were shown to be much inferior; with fillet welds, the major defect was porosity, while with butt welds flux inclusions and cracks were much more serious. Detection of defects in welds may be accomplished non-destructively by the use of X-rays; recommendations[76] have been published as to the best methods of making this examination. There is also now available a most useful book of typical radiographs,[77] illustrating the various types of defect, which has certainly supplied a long felt want.

The patrol boat "Dark Scout," shown under way off Anglesey, is the first all-welded aluminium vessel in the Royal Navy.

While considering fusion welding, reference must be made to its antithesis, arc cutting. Creswell[78] has described the development of tungsten-arc cutting for several metals including aluminium. The cut edges are suitable for welding without further preparation, and cutting speeds are high; for example, 1¼ in. plate may be cut at 50 in./min.

Published examples of the use of fusion welding of aluminium in various industries have not been lacking. A company in America is producing 1,500 ft./hr. of irrigation piping[79] on one line of equipment which forms, tungsten-arc welds, rolls and cuts the pipe automatically. Manual tungsten-arc welding is used to join the corners of aluminium window frames,[80] at a rate of one complete frame in four minutes. The body shell of the Austin Healey sports car[81] is made in alloy NS3, joined by tungsten-arc welding at a speed of 10 in./min. A surprising amount of fusion welding is involved in the construction of the Vickers Viscount airliner,[82] including gas and tungster-arc methods for both sheet and tube, and also some joints involving wrought and cast material. Archbold[83] has presented an account of the welding by semi-automatic and fully automatic means of the motor vessel *Bergensfjord*, involving a consumption of over 10 tons of filler wire and over 500,000 cu. ft. of argon. Welding for the fabrication of aluminium equipment in nuclear engineering has been discussed by Slater,[84] and the measures necessary to attain the high standards set in this field form the subject of a contribution by Burgess[85] to a nuclear power welding symposium. That exciting apparatus "Zeta" has an aluminium torus, made from sections of 1 in. plate in pure aluminium; the welding together of these and of associated pipework is described in a brief, but profusely illustrated article.[86] Birkhead[87] has devoted some attention to aluminium and its alloys in his general considerations of welding for chemical plant, and the largest all-welded aluminium storage tanks yet made in South Africa[88] have been described in words and pictures.

High frequency resistance welding[89] is being used in the U.S.A. to produce aluminium tubes from ½–10 in. diameter, at speeds up to 500 ft./min. and higher. Little has been published during the year about the spot welding of aluminium alloys, but one American company,[90, 91] is using automatic setting and control, with closed-circuit television, for the joining by this method of large aircraft panels. Cross-wire welding of aluminium alloys has not been applied in the past, but Batten[92] has carried out successful experiments on aluminium–1¼% manganese alloy. He shows that there is need for much closer control than when welding steel wire, and the process is slower, due to the longer period per spot and the need for accurate positioning. Moreover, careful cleaning of the wire before welding was essential; but specially coated wire overcame this difficulty. Stohr and Briola[93] have developed the welding of reactive metals in vacuum, using a series of successive spots, and have shown that the process may be applied also to aluminium.

Tylecote[94] and his co-workers have investigated the theory that the ratio of the hardness of the oxide film to that of the underlying metal might be important in determining weldability by pressure, and found that it is only of limited applicability. Where the film is thinner than 50 Å., and the metal work-hardens readily, the theory does not hold at all. In general, with pure aluminium, hard material requires somewhat less deformation than soft to give welds of equal strength. The term "forge welding" is applied by Cook and Shafer[95] to a technique whereby they press together two samples, and at the same time heat them externally to fairly low elevated temperatures, of the order of 175°–230° C. In high strength alloys, 95–100% joint efficiencies are claimed, with high elongations. Auxiliary heating, either by the use of preheated material or by resistance heating, has been shown by Jones and Meyer[96] to improve the strength of ultrasonic welds in clad and bare solution treated aluminium-copper-magnesium alloy. They made spot and seam welds in sheet up to 0·032 in. thick, and consider the achievement of welds of greater area to be only a matter of development.

Where large numbers of brazed joints are required,

and the necessary jigging or other means of assembly can be arranged, flux-bath brazing is the most rapid and economic method. Wernz[97] has given a general account of the process, and Slotta[98] has described its application to microwave components, which must be held to very close tolerances. The latter author uses his filler material in the form of a powder which is made into a paste and painted over the assembly before immersion in the flux bath.

The sticking together of metals continues to grow in scope, and Powis[99] has described recent developments in bonding for high speed aircraft, the material particularly mentioned being clad aluminium-copper-magnesium alloy. Failing loads of bonded joints were greater at 150° C. than those for riveted joints at room temperature. Adhesives are also used in the construction[100] of road-rail insulated containers in aluminium, and for the joining of drop-sides and tail-boards for lorries. A mechanical edge to edge joint[101] for aluminium sheet has been developed in Germany, based on the principle of interlocking teeth comparable to a slide fastener. The use of the wings of delta aircraft as integral fuel tanks rendered essential an efficient means of joint sealing, which had to be resistant to adverse conditions, including a service temperature range of −55° to 120° C., and the action of aircraft fuels. Spurgeon[102] has recounted the extensive research that led to the use of polytetrafluorethylene adhesive tape, which has proved completely satisfactory.

(to be continued)

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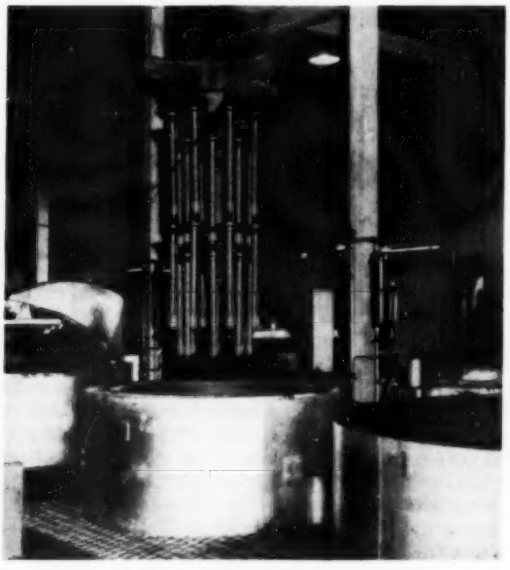
Hardening Axle Shafts

G.W.B. Installation at Standard Motors

THE Standard Motor Co., Ltd., of Coventry, are well known as the manufacturers of the Massey-Harris-Ferguson range of tractors. The axle shafts for this vehicle are, during their manufacture, subjected to a hardening and tempering treatment, and five electrically heated pit furnaces and accompanying oil quench tanks have been designed and supplied by G.W.B. Furnaces Ltd., of Dudley, to carry out the hardening part of the heat treatment cycle. Where parts, such as these axle shafts, of relatively long and slender dimensions require to be heated at high temperatures, it is considered that the pit type furnace, in which the components are suspended vertically, constitutes the best type of unit if distortion is to be kept to a minimum.

Thirty-two axle shafts, each weighing 37½ lb. comprise a furnace load, and they are carried in specially designed cast nickel-chromium jigs in two tiers of 16 shafts. The five furnaces are designed to produce an output of 4,000 hardened shafts per 120 hour week, working on a 3¾ hour heating cycle, of which 1½ hours are required for bringing up to temperature, while for the remaining 2¼ hours, the components are soaked at the required temperature. The furnaces themselves are capable of operating up to 1,050° C., although their normal working temperature is 950° C. At the time the installation was visited, the shafts being treated were, in actual fact, being hardened at 840° C.



Jig loaded with 32 axle shafts about to be lowered into the G.W.B. pit furnace. Part of the quenching tank can be seen bottom right.

Each furnace has a maximum electrical rating of 145 kW., arranged in one automatically controlled zone, governed by a Foster indicating controller with a 7 in. strip chart which gives a continuous visual record of the heating cycle. Delta/star rating reduction is provided, which reduces the input to one third of the maximum rating after thermal equilibrium has been obtained inside the furnace, and the soaking period then begins. This method of rating reduction is a desirable feature, since it reduces undue wear and tear on the electrical contactors. The vestibule opening of the furnaces is 3 ft. 2 in. diameter, while the depth is 6 ft. The loaded jigs hang vertically, suspended from four heavy arms at the top of the "spider" in slots of heavy cast heat resisting steel brackets which extend through the insulating bricks to the inside wall of the furnace casing. When the loaded jigs have been lowered into the furnace, the insulated lid is swung over into position, operating a limit switch which permits the heating current to pass to the elements which are of heavy nickel-chromium wire in coil form. These coils are arranged around the inside wall, supported on specially moulded open type firebricks. In addition to this safety limit switch, a further device to protect the charge and the furnace is fitted in the form of an excess temperature cut-out of the fusible type, which melts at a pre-determined temperature and cuts off the current to the heating elements through a relay in the control panel.

During the hardening period, a protective atmosphere is present inside the heating chamber to reduce scaling of the shafts to a minimum. At the end of the cycle, the shafts are lifted up and moved over by means of a hoist running on an overhead mono-rail, and plunged into the adjacent oil filled quench tank. The oil from all the five quench tanks is circulated through a common cooler situated outside the heat treatment shop.

After quenching, the shafts are then moved round to a washing and de-greasing machine before being transferred to the tempering furnace line for further treatment.

Change of Address

THE address of Metal Industries, Ltd., is now Brook House, Park Lane, London, W.1 (telephone: Hyde Park 6770).

New Radiation Pyrometer

Temperature Measurement in Induction Hardening

THE Wembley Research Laboratories of The General Electric Co., Ltd., have developed a radiation pyrometer for monitoring the surface temperature in an induction hardening process. The instrument consists of a thermopile specially constructed so as to give an electrical output substantially independent of ambient temperature over a wide range of source temperature. It may be used with a radiation collecting probe or with an aperture stop—or system of collimating stops—in the path of the incident radiation. Successful use has been made of a fused silica probe in an induction hardening and tempering process when the source area was small and was normally obscured by quench oil, spray and smoke.

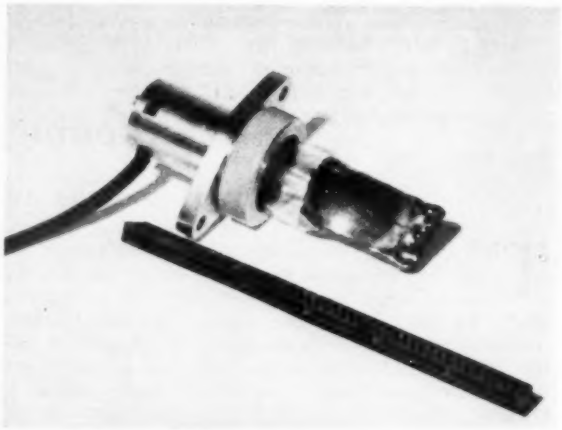
Applications

The pyrometer is not an absolute measuring instrument, and requires calibration in any particular application. Once calibrated, however, it has been found very consistent, and lends itself readily to a number of applications. Used with a probe it has been found suitable for measuring temperatures in induction melting, in hardening and tempering by a progressive method, and in cases where the source is obscured by intervening structures ; it can also be used for measuring temperatures of liquids and furnace charge temperatures. Without the probe, possible applications include the measurement of flame temperatures and the measuring of temperatures in extrusion and in sheet and strip rolling.

Principle of operation

A target body is mounted inside a cavity in a small aluminium block, and is almost completely enclosed. Because of its high thermal diffusivity and thick wall, the cavity may be considered as uniform in temperature.

A sheathed probe is used here to transmit radiation from the heated surface to the pyrometer : interference from smoke and oil spray is thus avoided.



A general view of the pyrometer head.

A narrow pencil of heat radiation is allowed to fall on the target through a small aperture in the cavity wall, so that the temperature of the target is raised above the temperature of the cavity. The device is normally stopped down so that the temperature difference is only a few degrees Centigrade. The steady temperature rise of the target above the cavity is then a measure of the amount of radiation absorbed by the target and, indirectly, of the temperature of the source of radiation.

The temperature differential of the target with respect to the cavity due to a given source of radiation changes only slowly with the temperature of the cavity itself, providing the temperature of the source exceeds a few hundred degrees Centigrade. For example, a pyrometer of this form changes its target temperature differential less than 5% for an ambient change from 15° C. to 50° C., when viewing a source at 300° C. Due to the sharply rising response of the pyrometer with source temperature, this represents an error in indicated source temperature of less than —6° C.

Performance

The output of the instrument naturally depends on the effective aperture of the pyrometer and the disposition and surface condition of the source of radiation. With full aperture the instrument responds to radiation from a cone of about 40° included angle, although the peak sensitivity occurs within a cone of 10° included angle.

Usually the instrument is stopped down to give about 1mV. of output which may be connected to a millivoltmeter or light-spot galvanometer. The response rate of the system in this case depends on the millivoltmeter, the response of the thermopile itself being very rapid. In fact, it is estimated that the thermal time constant of the pyrometer itself is of the order of 0·1 second.

Construction

Pyrometer Head :—The target body consists of a number of thermo-junctions of 0·004 in. diameter wires disposed radially in the cavity within the instrument. The reference junctions are welded to a segmented annular ring which is clamped between the two halves of the pyrometer case. A thin film of resin is used to insulate this assembly from the case. The segmented ring serves to connect the thermo-junctions in series, but its primary purpose is to establish good thermal bonding of the cold junctions to the case. At the aperture end of the case is a screwed clamping ring by which probes or aperture discs may be attached to the pyrometer. At this end mounting lugs are also provided.

Connection leads, in screened twin cable, are brought out at the other end of the device. Since these are normal copper leads of low resistivity they may be of considerable length with negligible loss of signal.

Silica Probe :—When the source is likely to be obscured by smoke or spray, or is otherwise inaccessible, it is convenient to fit a radiation transmitting probe between the source and the pyrometer. Probes have been made of polished rods of fused silica, ½ in. in diameter and used successfully up to 12 in. in length.

It is sometimes necessary to shield the air-to-silica surface of the probe from contamination by condensates, so that the transmission properties of the probe are undisturbed. A fused silica sheath has been used for this purpose, concentric with the probe and fused to it at the source end. At the pyrometer end the sheath is clamped to the instrument case with a rubber seal.

The transmission properties of fused silica are poor in the far infra-red, so that silica probes are unsatisfactory for use with source temperatures below about 400–500° C.

Basic Sizes for Sheet, Strip and Wire

AS the result of extensive publicity given to this subject, B.S.I.'s Committee MEE/-/7 was able recently to reach some definite conclusions on the problem presented by the multiplicity of sizes in current use. A summary of these conclusions is presented below.

Their first decision was that the S.W.G. is too well established a standard to supplant, so far as its use in Britain is concerned. The committee had to recognize, however, that there was no hope of getting the S.W.G. established as an international series under I.S.O. auspices. The strongest possible attempt to do this was made at the first meeting of the relevant I.S.O. committee in London in 1951, but was strongly resisted, largely because the Americans did not use the S.W.G. and would be most unlikely to accept it.

Committee MEE/-/7 then went on to consider whether they could contemplate the adoption in Britain of the range of thicknesses represented by the American preferred number series in inches. For this proposition there was support from the representatives of only one large firm ; the rest of the committee felt unanimously that it would confuse matters in this country rather than the reverse. A proposal that the S.W.G. should be modified to bring it into line with the American series was also rejected as being impracticable. It was felt that there was no adequate reason at present to disturb the current use here of S.W.G. and B.G.

The committee then faced the proposition that if they could not support the American proposal there was little hope of securing agreement among the inch-using countries on an inch series of thicknesses for the I.S.O. recommendation. The general feeling of the committee was that for international purposes the I.S.O. metric series already agreed upon would be sufficient, and that there would be no advantage in introducing a parallel inch series, and it was therefore agreed to inform the Australian Secretariat of Committee ISO/TC 62 that the United Kingdom had now reached the conclusion that the present I.S.O. recommendation should comprise the metric series alone.

In view of this recommended limitation it was felt that much of the argument for a system of code designations in addition to the metric thicknesses was removed, particularly as the metric countries in the I.S.O. committee had never shown any enthusiasm for a code or gauge designations. In this respect, the correspondence attracted by the previous publicity showed that British industry largely shared the Continental view on the matter. The committee did feel, however, that due importance should be given to a provision in the present draft I.S.O. proposal that the method of designating the thickness of sheet or diameter of wire should be by stating the basic size in millimetres, followed (if desired) by the letter " U " to indicate that this size belongs to the international metric series.

At an early date they intend to consider the domestic position with regard to the use of wire gauges. They would like to see published a British Standard giving full information both on the I.S.O. metric series as well as the series of gauges at present in general use in this country, and giving some clear guidance that may lead to a greater concentration of United Kingdom usage on the S.W.G. and B.G.

A Recent B.I.S.I.T.S. Development

FOR the convenience of users of the British Iron and Steel Industry Translation Service, it is proposed to issue periodical notices grouping together details of papers on specific subjects. The first of these group notices arises out of a meeting held in Düsseldorf on May 31st and June 1st, 1957, at which a series of tests on the behaviour of heat-resisting steels during creep testing at 500—700° C. were reported. The papers concerned appeared in *Arch. Eisenhuttenwesen* for May/June, 1957, and have been translated. Besides these items, translations are available of contributions of valuable data and experience made by experts from various countries who attended the meeting, and the verbatim reports of the discussions which were published in *Arch. Eisenhuttenwesen* for November, 1957. Further information can be obtained from the British Iron and Steel Industry Translation Service, 4 Grosvenor Gardens, London, S.W.1.

SUNVIC CONTROLS, LTD., announce that their London office is now at Crown House, Aldwych, London, W.C.2 (Telephone : TEMple Bar 8084).

Copper and Copper Alloys

A Survey of Technical Progress During 1958

By E. Voce, Ph.D., M.Sc., F.I.M.

Copper Development Association

Continued progress has been made in the past year in the metallurgy of copper and its alloys, and in the various sections of this review the author discusses the principal items of interest concerning such aspects as raw material resources, extraction, fabrication, finishing and properties.

OWING largely to labour unrest and other economic pressures in producing countries, the long-cherished hopes of stability in the price of copper have hardly been realised during the year just ended. Though such factors have not been without repercussions throughout the industry, they have in no way impaired technological advance, and the usual high standard has been maintained in the numerous publications which have appeared.

The Production of Copper

Mining Developments

It is pleasing to note that the British Isles have at last re-entered the fraternity of producers by the opening of a mine at Avoca, in Eire.[1] The mill is expected to export concentrates from about 4,000 tons of ore daily. Other mines to have come into production recently are those at Tilt Cove in Newfoundland[2] and on Vancouver Island.[3]

Among discoveries of copper ore, several have been reported from Poland,[4, 5] another in Jamaica,[6] and a third on the Sherritt Gordon property in Canada.[7] French and Belgian interests are reported to be assisting production in Yugoslavia, where there are extensive reserves.[8, 9] Work has started on a second open-cast mine at Nchanga on the Copperbelt of Northern Rhodesia,[10] while at Kilembe it is planned to exploit large reserves of oxide ores available near the surface.[11]

Hydrometallurgy

The industrial applications of cation exchange, using resins, are gaining ground in many directions ; a German patent for the extraction of copper from acid leaching solutions by this technique has appeared.[12] To determine optimum conditions for the acid leaching under pressure of chalcopyrite, chalcocite and covellite, Warren[13] has examined the influence of such variables as temperature, acidity, partial pressure of oxygen and surface area on the rate of oxidation. The regeneration of spent leaching solutions consisting of acid ferric sulphate by aeration in the presence of autotrophic bacteria has been developed by the Kennecott Copper Corporation.[14]

Pyrometallurgy

Theys and Lee[15] have described experiments leading to the construction of an efficient roaster for sulphide concentrates containing copper and cobalt in the Belgian Congo, while a new type of fluid-bed roaster has been developed in Australia.[16] Two somewhat academic investigations are potentially of value in connection with matte smelting: Johannsen and Wiese[17] have examined the settling behaviour of drops of matte and copper in molten silicate slags with a view to improving the yield of copper, while Bourgon, Derge and Pound[18] have measured the densities of molten cuprous sulphide, ferrous sulphide and a mixture of the two at temperatures ranging from the liquidus to 1,500° C. Cunningham and Wooddell[19] have patented the addition of silicon carbide to the charge of a copper reverberatory furnace with the object of decreasing the amount of magnetite.

Electrolysis of Molten Copper Sulphide.

For some years investigators at Cambridge University have been working on the electro-decomposition of molten cuprous sulphide. A publication by Hoar and Ward[20] envisages the possibility of large-scale production of copper and sulphur in this way (compare ref. 252).

Refining and Remelting

The increasing demand for electrolytic copper is reflected in the construction of three new refineries, respectively near Baltimore by the Kennecott Copper Corporation,[21] at Pirlop in Bulgaria[22] and in Turkey.[23] On the other hand, the British refinery of McKechnie Bros., Ltd., has been closed for economic reasons.[24] An account of refining practice at Copper Cliff[25] pays particular attention to quality control through the use of addition agents during electrolysis. In connection with the production of OFHC brand copper, Kinnumen and Merikanto[26] give analytical methods for the determination of sulphate contaminating the cathode.

Based on investigations by the British Non-Ferrous Metals Research Association, two papers have been published on the removal of lead[27] and of both lead and tin[28] from copper during fire refining. What is stated to be the world's largest electric melting furnace for copper has been put into operation at the Perth Amboy plant of the American Smelting and Refining Co.[29] The same company has adapted its now well-known continuous casting process to the production of tough pitch copper cakes 25 ft. long × 36 in. wide and 5 in. thick.[30, 31] Tower and Brown[32] maintain that, despite high initial cost, the all-basic suspended type of roof for wire bar furnaces effects substantial overall economies.

Foundry Practice

The 25th International Foundry Congress

While contributions to the International Foundry Congress held this year at Liège, Belgium, include many

which are of general interest to foundrymen, only two are specifically related to copper. The first of these is an important paper by Hudson, Wood and Gregg[33] on the properties of copper-base alloy castings. The authors tentatively recommend a gunmetal containing 6–7% tin, 3–4% zinc, 3–4% lead and 1·5–2·5% nickel as a general-purpose foundry alloy. The second of the two papers mentioned is by van Bleyenberghe and Coussement[34]; it deals from a practical point of view with additions of copper to cast steel and iron, and indicates that such additions facilitate foundry operations.

Melting

The mains frequency coreless type of induction furnace is rapidly gaining recognition, particularly on the Continent. A recent contribution to the literature of this subject is a paper by Rohn,[35] which refers specifically to the melting of non-ferrous foundry alloys, including those based on copper.

A practical account of the vacuum melting of copper-base alloys, among other materials, has been issued,[36] with data on the improvement in mechanical properties which can be obtained by this technique. The problems of vacuum melting have been discussed in more general terms by Loria[37].

Oil firing of furnaces for melting copper and copper alloys leads to the possibility of contamination of the melt by sulphur. Buttkereit[38] outlines precautions to be taken against excessive absorption of sulphur and gives methods for desulphurising molten metals. On the other hand, experimental work by Reiter[39] has demonstrated that sulphur in amounts up to 0·3% has no deleterious effect on 85 : 5 : 5 : 5 and 88 : 10 : 2 gunmetals or 90 : 10 phosphor bronze, in the sand-cast condition.

Moulding Methods

Zeiser[40] discusses cement-sand mixtures for the production of Randupson-type moulds, paying particular attention to the various grades of cement which are available and to the applications for which each of these is suitable. A note of Australian origin,[41] gives information on the advantages of including zircon sand in both core- and green-sand mixes, while Johnson[42] recommends the general use of oil-bentonite bonded moulding sand for brass and bronze castings, in place of the more orthodox bentonite-water sand.

Harris[43] attributes certain cases of embrittlement in copper castings made in shell moulds to a reaction between reducing gases from the heated resin and oxide in the melt. He explored the use of titanium, lithium, phosphorus and calcium boride as deoxidants to combat the difficulty, and pronounced in favour of titanium and lithium. Two British patents[44, 45] refer to precision casting by the "Investment X" process; they are concerned with suitable mixtures for the refractory coatings of the wax patterns, and with the coating procedure, respectively. Marsel, Kramer and Saunders,[46] give valuable information on the selection of waxes for precision investment casting.

Diecasting

Billing[47] describes techniques suitable for the gravity die-casting of brass, aluminium bronze and other alloys of copper, indicating measures to be taken to remedy the principal defects which are likely to arise, and Miller[48] reviews the mechanisation of gravity dies, with the object of reducing fatigue on the part of the operator. Barton[49] deals with the failure of dies by heat checking (or surface crazing), stressing the importance of avoiding undue temperature fluctuations. A bibliography on permanent mould casting, first prepared by the American Foundrymen's Society in 1946, has been extended to include literature up to 1955.[50]

Continuous Casting

The British Iron and Steel Research Association has developed a new type of continuous casting machine which features a spring-mounted mould in place of the more usual reciprocating mould,[51] and Junghans[52] one which incorporates a rotating magnetic field. A useful review of the various continuous casting methods now in operation, with up-to-date output figures, has been written by Easton,[53] and, according to a statement by Winkle,[54] the Durville casting of beryllium copper has been abandoned by the Brush Beryllium Co. of America, in favour of semi-continuous casting.

Control of Quality

The Institute of British Foundrymen is at present attempting to develop a reliable test for melt quality prior to casting, but according to an interim report,[55] it is still not possible to recommend any one test for universal application. Moore[56] suggests that the gas content of copper alloys with a wide freezing range can be satisfactorily assessed by removing a sample from the melt, converting it into an alloy of short freezing range, and estimating the gas content in a vacuum apparatus. As an example, a long freezing range tin bronze or gunmetal containing about 10% tin can be instantly converted into a short freezing range alloy carrying 35% tin by pouring the sample into a suitable quantity of molten tin.

Flinn and Mielke[57] describe the effects of four important variables, namely pouring temperature, moisture content of green sand, chilling and depth of machining upon the pressure-tightness of castings in 85 : 5 : 5 : 5 leaded gunmetal, while the Institute of British Foundrymen[58] has studied the influence of a number of factors on the surface quality of non-ferrous sand castings.

Waterhouse[59] gives tensile and impact data at temperatures ranging from −55° C. to +70° C., on several gravity die cast brasses and aluminium bronzes, and, by careful experiments, Hendry and Wrightson[60] have demonstrated that a significant expansion of the solid shell occurs throughout the period of solidification in the case of copper-base and light alloy castings.

A New Bearing Metal

A complex bearing alloy containing 2–5% each of tin and zinc, 1–3% of silicon, and a total of 2–4% nickel, iron and lead has been developed in France.[61]

Fabrication

Rolling

The influence of high rates of deformation in strip rolling has been investigated by Christopherson and Parsons,[62] and, from Poland, Tychowski and Olszewski[63] advocate the production of narrow strip by drag rolling from wire. Simms[64] has reviewed developments in the field of automatic guage control, and considerable interest has been aroused by the installation of a device for the purpose in a Birmingham brass mill.[65, 66, 67]

Hot and Cold Extrusion

Three important papers on the hot extrusion of metals

have appeared. One of them, by Haffner and Elkan,[68] deals with extrusion presses and their ancillary equipment; Bishop[69] discusses the mechanics of the process in considerable detail, while Hirst and Ursell[70] define limiting factors, such, for example, as the effect of speed on incipient melting.

The Mechanical Engineering Research Laboratory at East Kilbride[71] is using copper and 70 : 30 brass among other metals and alloys in a practical investigation of cold impact extrusion. Galloway[72] has determined the influence of the thicknesses of wall, base and slug on the force required to reverse-extrude copper and other materials, at temperatures ranging from 14° C. to 250° C. Impact extrusion practice has been reviewed by Byles.[73]

Hot Pressing and Forging

A new development, emanating from Austria, is that of a machine which produces hot forgings continuously from bar stock, the forgings being subsequently separated by a clipping operation,[74] and a closed-die type of forging machine capable of operating cores at 45° to the direction of the main stroke of the press has been devised.[75, 76]

Data on the induction heating of brass and other billits with industrial frequency currents have been given by Zuev,[77] and Hammarlund and Sundberg[78] point out that, as forging machines become more rapid in operation, induction equipment is increasingly replacing conventional furnaces for billet heating.

Cold Presswork

As an outcome of the formation of the International Deep Drawing Research Group a year ago, a similar British Group has been inaugurated,[79] with the object of maintaining full liaison with the international body and of encouraging research on deep drawing problems. The influence of speed in deep drawing is discussed by Coupland and Wilson[80] on the basis of experimental results, while Tychowski and Wianiewski[81] have developed a technique of combining a cupping draw with a reverse re-draw.

A process known as " compression forming " has been developed for sheet metal.[82] The edges as well as the surfaces are subjected to compression, forcing the metal to flow and to set against the face of the die, with greater precision than that obtainable by normal techniques. Another development is a modification of the conventional Guerin process in which the rubber punch is mounted on a drop hammer so that the local pressures exceed those normally encountered.[83] In an extension of the process, the rubber punch is propelled against the metal by the explosion of a shot-gun cartridge. Paulton and Colding[84] give information on the use of rubber diaphragms in presswork operations, and also of a new concept of spinning, known as shear spinning.

The Production of Tube, Rod and Wire

The production of Bundyweld steel tubing has been described.[85] Steel strip, previously electroplated with copper, is rolled to form a double-walled tube, which is subsequently brazed by melting the coating of copper. A somewhat similar process for the formation of hose from nickel-iron strip is outlined by Schaefer and Admerand.[86] The strip is fed into a winding machine together with a copper wire with which it is brazed.

Neumann[87] compares the " Rockrite " cold reducing process for tubes with ordinary cold drawing, and includes fabricating experiences with copper and aluminium bronze among other materials. According to a British patent,[88] lead-covered copper rod or tube is made by coating the copper with solder and passing it through a lead extrusion press. The main use of such a product is for anodes in chromium plating.

After reviewing various wire drawing theories in the light of modern knowledge, Whitton[89] presents a new expression which permits the rapid and simple calculation of drawing forces over a wide range. Wistreich[90] has published a useful appraisal of lubricants for wire drawing.

Cutting Processes

An important contribution to knowledge of the mechanism of cutting processes for metals has been made by Jouty[91], and Pugh[92] reviews the attempts which have been made to solve the problem of orthogonal cutting.

Tilsley and Howard[93] have studied the blanking and piercing of soft copper plate, $\frac{3}{8}$ in. in thickness, and also of mild steel, and conclude that a clearance between punch and die of 10% of the metal thickness per side gives a satisfactory sheared surface. Brinkworth[94] has carried out a series of experiments on the shearing of thin copper and aluminium foils at cutting speeds up to 120 ft./sec.

The development of cutting fluids and their methods of application is the subject of a review by Morton[95], while Neppiras[96] deals with the design of cutting tools which vibrate at ultrasonic frequencies. Rudorff[97] has published a useful review of the present status and potentialities of machining by spark erosion, and the production of small deep holes, for example, 0·03 in. diameter and 4 in. deep, by this method has been recently described.[98] According to La Salle Steel Co.,[99] the addition of copper to cold finished steel bars greatly improves machinability.

Bright Annealing

Peck[100] gives a general review of modern bright annealing practice, mentioning specifically the conditions required to ensure minimum volatilisation of zinc from brass; and the General Electric Co., Ltd.,[101] has patented a technique for the bright annealing of brass in closed containers of mild steel.

Plating and Finishing

Electrodeposition of Copper

The electrodeposition of copper on aluminium has been mentioned in several previous surveys. A note[102] indicates that such a process is now in commercial use on aluminium wire and strip. Two further papers on the subject have appeared. In one of them, Atkinson[103] describes a bath which consists of citric acid, copper sulphate and a soluble fluoride: he claims that the only preparatory treatment required is degreasing. The second method[104] is a modification of oxalate copper plating.

A sulphur-copper bath containing a thiazine dye as brightener is claimed to allow of wide variations in solution concentration and current density without burning or treeing[105]. The proprietary Cupatier process for bright copper plating from an acid sulphate electrolyte has been described by Strauss and Roth.[106] A new development, emanating from Russia, is a cyanide-free electrolyte incorporating an alkali metal sulphide for the deposition of copper directly upon steel.[107]

Electrodeposition of Brass and Bronze

A patent by Ostrow[108] covers a bright brass bath containing copper cyanide, an alkali metal cyanide, a soluble complex zinc polyamine and an alkyl polyamine, while another, by the Ford Motor Co.[109] deals with white brass plating from an alkaline cyanide solution of copper and zinc with a two-cycle reversal of current, the cycles having different frequencies.

Raub and Sautter are engaged in the investigation of the structure of electrodeposited alloys by X-ray diffraction microscopy, reflectivity measurements and microhardness. One of their publications[110] covers copper-tin alloys ranging from about 86% downwards to 13% of copper.

Chemical and Electrolytic Polishing

Experiments by Lorking[111] have indicated that the optimum conditions for macro-and micro-electropolishing of copper are achieved in orthophosphoric acid solutions at concentrations of about 600 g./l., and that it is beneficial to increase the viscosity of the electrolyte by the addition of a relatively small quantity of metaphosphoric acid. In contrast, Zak[112] has reported that electropolishing in phosphoric acid is inefficient in corners and crevices. For chemical polishing he recommends a mixture of phosphoric, acetic and nitric acids in the proportion of 50 : 30 : 20 parts by volume. A review by Tomkins[113] covers the theory, mechanism and applications of electropolishing on a broad basis, and Spencer[114] has dealt with chemical polishing in a comparable manner.

Cleaning Processes

Information[115] has appeared concerning the use of ammonium persulphate for the removal of oxide films and stains from copper and brass. The recommended concentration is 25% by weight of ammonium persulphate in water. Patents by Ruff and Smith[116] deal with various solutions, ranging from organic detergents to salts of a variety of metals, which are claimed to deter tarnishing on copper and copper alloys, particularly nickel silver. In more general terms Matteson[117] has surveyed the available information on the staining of copper and brass, paying special attention to water stains and those caused by hygroscopic surface contaminations. Similar in scope is a paper by Hooper,[118] who classifies the causes of surface stains and gives advice upon avoiding them.

Other Surface Treatments

A patent by the General Electric Co., Ltd., for the anodic oxidation of copper wire has appeared,[119] and an investigation of the anodic oxidation of electrodeposited speculum metal has been reported.[120] A proprietary solution for the chemical colouring of copper and copper alloys has been announced under the name of Enthocolor 220. It is claimed that these coatings do not spot, and can be severely deformed without cracking.

Blackman, Dewar and Hampson[122] have made a special study of organic compounds which cause moisture to form discrete droplets on copper surfaces. The object of the work was to improve the performance of condensers, but it seems possible that the results might also be useful in connection with the artificial patination of copper roofs, where it is desirable that the patinating solution should form droplets.

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Inert Gas for Purging

FUEL gases of all kinds can form explosive mixtures with air. The pipes, tanks, gas holders and process vessels used in the manufacture or handling of fuel gases need to be emptied from time to time, but before air can be let in, fuel gas must be removed by purging with a suitable inert purge gas. When the plant is again ready for operation, the system must be purged with inert gas to ensure the removal of all traces of oxygen to avoid the possiblility of explosion. In connection with needs of this kind, the Dryer and Gas Plant Division of Birlec, Ltd., is at present engaged in designing an inert gas generator with a capacity of 200,000 cu. ft./hr. In the design, air mixed with propane is deliberately ignited within an enclosed cylinder, and the inert gases generated by the combustion are collected and employed in the purging process. Development work on inert gas generator design is at present being carried out by the Company to establish the optimum sizes of burner for a wide range of generator capacities.

Change of Address

THE South Eastern area office of Birlec, Ltd., manufacturers of heat treatment furnaces, dryers and gas plants, has been transferred to Crown House, Aldwych, London, W.C.2. (Telephone number: Temple Bar 8040.) The South Eastern area office of Birlec-Efco (Melting), Ltd., has also been established at the same address.

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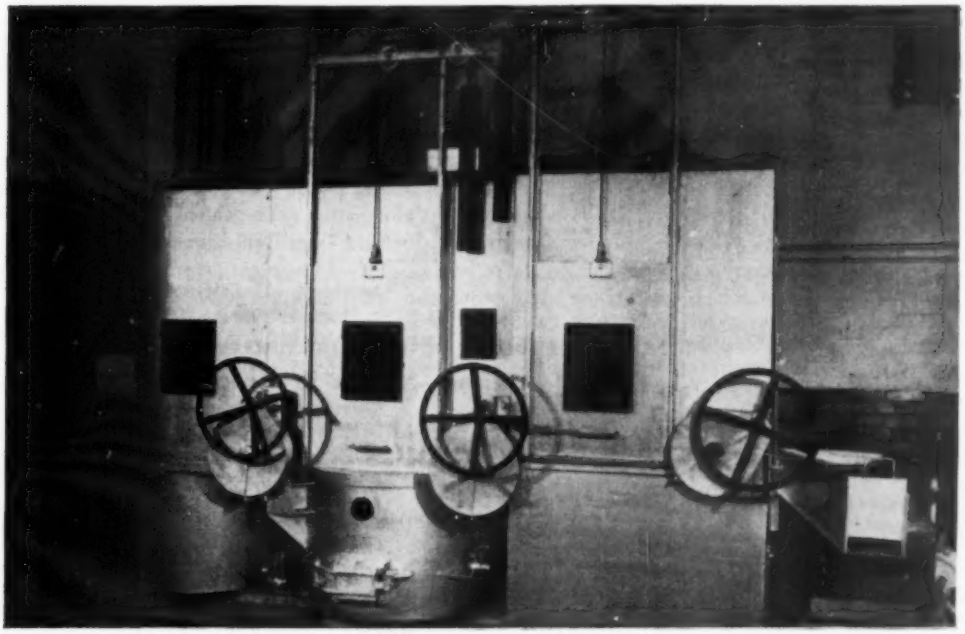

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NEWS AND ANNOUNCEMENTS

Powder Metallurgy Meeting Postponed

THE next meeting of the Powder Metallurgy Joint Group of The Iron and Steel Institute and The Institute of Metals has had to be postponed from March 12th until Wednesday, April 29th. The meeting will consist, of the presentation and discussion of a series of papers on "Theoretical Aspects of Sintering," which will be published in advance of the meeting in the next issue of the Group's periodical *Powder Metallurgy*. The meeting will be held at Church House, Great Smith Street, Westminster, S.W.1., commencing at 9.30 a.m. Visitors will be welcome; tickets are not required.

On the evening of the meeting, there will be an informal conversazione at the Headquarters of the Institute of Metals, 17 Belgrave Square, London, S.W.1. Tickets for this function will be limited to about 200, and will be restricted to members of the two Institutes and their personal guests.

Flame Hardening Conference

A FLAME HARDENING CONFERENCE, organised by Firma Paul Ferd. Peddinghaus of Gevelsberg, West Germany, will be held at the Haus der Technik in Essen on March 16th and 17th, 1959. Among the subjects to be discussed will be the application of flame hardening to cold steel rolls, track links, tractor chain links, cast iron gears, stainless steel in relation to the manufacture of high pressure valves for superheated steam, Blackheart malleable cast iron, die blocks and press tools, and boring tools. There will also be papers on a new source of energy for surface hardening, internal stresses set up in components by flame hardening, and tests carried out on the wear of worms. The papers will be given in German, but will be simultaneously interpreted to British visitors by means of an ultra short wave transmitter, so that papers can be closely followed. Application forms for attendance and hotel reservations can be obtained from Surfard, Ltd., Abford House, 15 Wilton Road, London, S.W.1.

Plate Mill Drive Contract

FOLLOWING the recent successful commissioning, on schedule, of a new 8,000 h.p. twin-motor reversing plate-finishing mill at their Appleby Steelworks, the Appleby-Frodingham Steel Co., Scunthorpe, has awarded another important contract to the newly-formed A.E.I. Heavy Plant Division at Trafford Park. The contract calls for the supply, delivery, and erection of the electrical main drive equipment for a new 12-ft. twin-motor reversing plate-roughing mill, which will replace an existing mill and which will operate in conjunction with the recently commissioned finishing mill. It will roll slabs weighing up to 25,000 lb. down to dimensions suitable for finish rolling in the finishing mill, the two mills being situated in line to facilitate ease of transfer and to reduce handling size.

The new mill will be of conventional two-high construction, having two work rolls 46 in. diameter × 12 ft 6 in. long. Each roll will be driven by a 3,000 h.p. (r.m.s.), 40/80 r.p.m., 1,000 volt D.C. motor, and the maximum peak output from the twin-motor drive will be 18,000 h.p. The mill will be controlled by means of a light, hand-operated master controller. The electrical control scheme will use amplidyne rotating amplifiers operating in conjunction with laminated yoke exciters. This gives rapid rates of response to the demands of the operator, and reversal times of the order of 3 sec. from top speed forward to top speed reverse. The main motor-generator set, a duplicate of that supplied for the finishing mill, will comprise four 1,060-kW. generators, a 6,000 h.p. induction motor, and a cast-steel flywheel weighing approximately 32 tons.

In addition to supplying the above equipment with its control gear, the Division will also act as main contractors for the cable installation and the ventilation equipment necessary to provide the cooling air to the machines.

Change of Address

SINTERING & BRAZING FURNACES, LTD., have acquired additional premises at 124a–130, Edinburgh Avenue, Trading Estate, Slough, Bucks., and offices have been established there. All future communications should be sent to this address: the telephone numbers are Slough 21143 and 24011, and the telegraphic address is "Sintbraz, Slough."

G.E.C.—Via-Vac Alliance

THE General Electric Co., Ltd., announces that an agreement has been reached with Vacuum Industrial Applications, Ltd., of Wishaw, Lanarkshire which combines the considerable resources of the two companies in the vacuum heating field for the development of vacuum heating techniques and the design and manufacture of complete vacuum furnace installations. Both companies have considerable experience in this field. Vacuum Industrial Applications, Ltd., who specialise in industrial vacuum equipment, including pumps, gauges, valves and pipelines, have themselves designed vacuum furnaces using induction heating units, including dual purpose equipments with alternative resistance heating units. The G.E.C are well known as pioneers of electric furnaces and as specialists in the development of controlled atmosphere processes. Acting jointly, the companies command excellent facilities for research, design and manufacture and are well equipped to meet demands for complete installations for vacuum melting, sintering, brazing, degassing, stream degassing and general heat treatments. Under the terms of the agreement enquiries will be handled by The General Electric Co., Ltd.

Australian Instrument Exhibition

THE first Australian exhibition of automatic analytical instruments is to be held in the Sydney showrooms of Watson Victor, Ltd., during the fortnight beginning February 23rd, 1959. The instruments, with a total value of about £35,000 will be representative of those made by the London firm of Hilger & Watts, Ltd., and it is indicative of the faith this firm has in the Australian market (and in the willingness of the Australian manufacturer to accept new methods) that they are prepared to make so heavy an outlay for exhibition purposes.

Their Sales Director, Mr. D. R. Stanley, will be at the exhibition together with technical specialists from this country. Among the exhibits will be equipment for the rapid analysis of steel and non-ferrous alloys.

Personal News

THE Research and Development Department of The United Steel Cos., Ltd., has announced a number of organisational changes. DR. W. DAVIES, Head of the Minerals Section, has been additionally appointed Geological Consultant to United Steel, in recognition of his special contributions in this field. Because of his long secondment to Barrow Steel Works, Ltd., MR. I. M. D. HALLIDAY has relinquished his interest in furnace design and is formally in charge of continuous casting research; MR. C. HOLDEN is appointed Head of the Furnace Research Section, which was formerly known as the Furnace Design Section. MR. A. S. BABB is to take charge of a new Trackwork and Structures Section in the Department; this will form a part of the Development Engineering Group. MR. D. SHAW is appointed Head of the newly created Electronics Section.

THE ENGLISH ELECTRIC CO., LTD., announces that MR. H. G. NELSON, Managing Director of The English Electric Co., Ltd., has also been appointed Deputy Chairman of the following subsidiary companies of the Group: D. Napier & Son, Ltd., Marconi's Wireless Telegraph Co., Ltd., Marconi Instruments, Ltd., English Electric Valve Co., Ltd., Vulcan Foundry, Ltd., Robert Stephenson & Hawthorns, Ltd., and of the associated company, The Marconi International Marine Communication Co., Ltd.

HADFIELDS, LTD., announce the following changes in and additions to the Boards of certain of their subsidiary companies. MR. E. W. COLBECK becomes Deputy Chairman of Hadfields Steels, Ltd., in addition to Managing Director, and MESSRS. G. WOOD, F. COUSANS, and G. J. JENKINS have joined the Board.

Weighing over 40 tons each, the two largest cast steel rolls ever produced on the Tyne were shipped recently to Germany for installation in one of the largest slabbing mills in Europe. Of heat treated alloy steel, the rolls were made by Armstrong Whitworth (Metal Industries), Ltd., and the order was obtained in the face of Continental competition on the quality of production.

MR. W. J. GIBSON, J.P., has been appointed Deputy Chairman, and MR. G. WOOD, Managing Director of Hadfields Forgings, Ltd., and MESSRS. T. PEASE and D. R. WARD have joined the Board. In Hadfields Foundry and Engineering Co., Ltd., MAJOR H. G. FREEMAN is now Deputy Chairman, MR. F. COUSANS Managing Director, and MESSRS. F. HOLMES and G. J. JENKINS have been appointed Directors. MR. H. HUMPHRIES, Deputy Chairman and Managing Director of Hadfields, Ltd., is Chairman of each of these Subsidiaries.

MR. J. SIMPSON, Joint Managing Director, has been appointed Deputy Chairman of Woodall-Duckham Construction, Co., Ltd., in which position he will carry special responsibilities relating to the operations of the growing number of subsidiary companies within the Woodall-Duckham Group at home and overseas. In this connection he left England in January for a six months' visit to Australia and New Zealand. MR. E. N. WENBORN, who joined the Company in 1924 and has been on the Board since 1957, has been appointed a Joint Managing Director.

MR. A. R. WOODWARD had been appointed Head of the Joining Division of the Development Department at Aluminium Laboratories, Ltd., Banbury. He will be responsible for the investigation and development of all methods of joining aluminium, with particular reference to welding.

EDGAR ALLEN AND CO., LTD., have appointed MR. R. E. SHERWOOD as Manager of the Steel Department, in succession to MR. F. M. DARLOW who retired on October 30th, 1958.

THE English Electric Co., Ltd., announces that in view of the continuing expansion of the Company at home and overseas and of the wider responsibilities now carried by members of the central management, the appointments of the following executives have been re-designated as follows: MR. E. B. BANKS is appointed Director of Commercial Policy, Contracts and Sales; MR. P. L. DE LASZLO, O.B.E., is appointed Director of Corporate Affairs; MR. W. M. HURTON is appointed Director of Group Manufacturing Development and MR. L. H. SHORT, M.C., is appointed Director of Overseas Operations.

MR. J. P. LEWIS has been appointed General Manager, and MR. T. R. H. WADSWORTH Assistant General Manager, of the British "Rema" Manufacturing Co., Ltd., a subsidiary of Edgar Allen and Co., Ltd.

AFTER almost 50 years with Geigy, MR. C. F. GYSIN retired at the end of 1958 as Chairman of the Board of Geigy (Holdings), Ltd., of Manchester. MR. E. G. TURNER succeeds Mr. Gysin as Chairman of Geigy (Holdings), Ltd., with MR. H. L. ADDLESHAW continuing as Deputy Chairman. MR. H. CLAYTON succeeds Mr. Turner as Chairman of The Geigy Company, Ltd., with MR. H. JONES as Deputy Chairman; Mr. H. Jones and MR. G. A. CAMPBELL become Joint Managing Directors. MR. ADDLESHAW succeeds Mr. Gysin as Chairman of Ashburton Chemical Works, Ltd., of Trafford Park, Manchester, with DR. F. BUCHMEIER as Managing Director. On the Board of James Anderson & Co. (Colours), Ltd., of Paisley, MR. A. H. WHITAKER succeeds Mr. Gysin as Chairman, and MR. A. A. R. OSBOURNE and DR. D. M. STEAD become Joint Managing Directors.

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

Magnesium Sheet Alloy for Welding

A NEW magnesium sheet and plate alloy that does not require stress relief after welding has been developed by The Dow Chemical Co. The alloy, ZE10A, which contains zinc and rare earth metal as alloying constituents, has the best toughness of any magnesium sheet alloy now on the market, according to Dow. It is in full commercial production and is available for overseas markets through the facilities of Dow Chemical International, Ltd., S.A., and its sales representatives. Elimination of the need for stress relief after welding makes ZE10A advantageous in large structures and in field repair operations where stress relief is difficult to apply. Possible applications include storage containers, shipping containers for commercial bulk products, and tank-trailer bodies.

Typical mechanical properties for ZE10A in the H24 temper (strain hardened, then partially annealed) include: tensile, 38,000 lb./sq. in. (17 tons/sq. in.); tensile yield, 28,000 lb./sq. in. (12·5 tons/sq. in.); compressive yield, 26,000 lb./sq. in. (11·6 tons/sq. in.). The alloy also is furnished in the –O temper (fully annealed). To obtain the full benefits of ZE10A when welding it to magnesium extrusions, an extrusion alloy that likewise does not require post-welding stress relief should be chosen. These include a new extrusion alloy, ZK20A, and the older M1A alloy.

Dow Chemical International, Ltd., Midland, Michigan, U.S.A.

The Elcotector

THE Elcotector is an instrument designed to carry out a large number of measurements in a non-destructive manner. Its primary use is for all types of coating measurements on components. In addition, it is capable of measuring the thickness of most metallic and non-metallic foils in both the static and moving states; it can thus be applied to the production run to give continuous readings of thickness as material is produced.

Based on the eddy current principle, it is claimed that, due to its special construction, the Elcotector has overcome the difficulties which have been experienced in applying this principle in the past. As the instrument operates " on tune " position it has very great stability, and one unit with one standard probe head can be used for all manner of tests. The device makes use of the fact that the electrical characteristics of a coil are influenced in proportion to its proximity to a metal surface. Under suitable conditions a meter is capable of translating these changes in the coil into measurements of non-metallic coating on metal. The coil is also influenced by the type and structure of the metal, i.e., these changes can be translated into metal film thickness, metal hardness and like measurements.

The coil in the case of the Elcotector is situated in the head of the probe which is presented to the surface under test. Two types of probe are available—one in the form of a short pencil for general purposes, the other with a

short head and angular extension to enable its use in narrow confined spaces—these two being used for hand checking purposes only. For continuous strip measurement, special probes can be produced capable of accommodation on any specific machine. They can be housed in P.T.F.E. frictionless material, and so lightly balanced as not to affect even the most delicate material. Hollow cup or pot coils are provided for repetitive hardness measurement of such small tools as drills, plug gauges, taps, steel balls, etc.

The sensitivity of the unit varies according to the type of work and can furthermore be adjusted at will over very wide limits. The following are given as typical examples :—

Type of Measurement	*Full Scale Reading at One Setting of Coarse Range Control*	
	Maximum Sensitivity	*Minimum Sensitivity*
(1) Plastic coating on aluminium ..	0–0·008 in.	0–0·175 in.
(2) Plastic coating on steel	0–0·007 in.	0–$\frac{1}{8}$ in.
(3) Plating on steel..	0–0·0005 in.	0–0·010 in. or more

Due to the extreme sensitivity of the instrument in measuring foil thickness, it is not possible with the standard unit to obtain a wide range of thickness variation at one setting of the control. In most cases this characteristic is a considerable advantage since extreme accuracy of reading is thus possible. A small inexpensive accessory can be provided to reduce this sensitivity if required for special work. There is a " boundary " limit of maximum thickness measurement for all metal coatings or foils, dependent upon the metal resistivity. For copper it is 0·010 in. and for aluminium and brass 0·020 in.

The makers claim that the Elcotector is capable of measuring (*a*) the thickness of any type of coating, metallic or otherwise on a steel case; (*b*) the thickness of non-metallic coatings on most metal bases and some metallic coatings, provided the specific resistances of coating and base are different; (*c*) the thickness of

non-ferrous metal foils; and (*d*) the thickness of non-metallic films where a metal plate can be introduced at the reverse side at the point of measurement. It can also be used for comparing the hardness of steel components; for differentiating between various types of alloy; for comparing ferrite contents in austenitic steels; and for surface crack detection. Furthermore, the makers are willing to undertake experimental work on specific problems submitted to them.

East Lancashire Chemical Co., Ltd., Fairfield Road, Droylsden, Manchester.

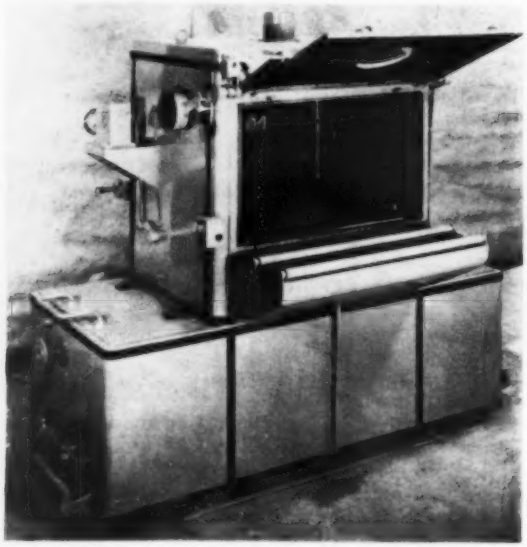
Precision Pulse Generator

ALTHOUGH designed primarily for accurate measurement of pulse height analyser channel threshold and width, this new instrument from Sunvic Controls, Ltd., will be of great value in many other applications in which a shaped pulse of stable and accurately known amplitude is required. The instrument consists of three main sections: stabilised power supply, voltage divider network, and pulse forming network. Pulse amplitude is adjustable over the range 0–40 V. by the main control, and there is also incremental control which provides continuous variation over a range of 0–1·2 V. with a linear accuracy of ±2 mV. Overall amplitude stability during an 8-hour period is better than ±0·05% (allowing for mains variation of ±5%). A three-position switch selects pulse widths of 1, 5 or 25 micro-seconds. Pulse polarity may be either positive or negative at a repetition rate equal to mains frequency. Dimensions of the instrument are approximately 11 in. high × 19 in. wide × 10 in. deep; the weight is 30 lb.

Sunvic Controls, Ltd., 10, *Essex Street, London, W.C.2.*

Single-Chamber Metal Washing Machine

I.F.A. ENGINEERING CO., LTD., sole agents in the U.K. for Wache plants for the surface treatment of metals, have announced the introduction of a new type of metal washing machine which, although consisting of one chamber only, performs the task of a plant of two or three chambers. Using the spray method, it is suitable for pickling, degreasing and phosphating of all metal components.



The wire basket containing the work to be treated is inserted into the spray chamber and the door closed by hand. The action of closing the door starts the stop clock, and the pre-set working sequence is commenced. First, the degreasing or treatment pump and rocking gear for oscillating the basket are switched on. At the end of a set time this pump is switched off and the tipping plate positioned to return the liquid to its specific tank. This is followed by the starting of the next pump and so the operation is repeated twice more. On completion of all these operations a signal light is switched on automatically to indicate to the operator that the treatment of the work is finished, and that it can now be removed from the spray chamber. Two or three thermometers, each with a range of 0–120° C., are fitted to the machine to check and control the temperatures of both the treatment solution and the hot water for the rinse.

The machines are available in three different sizes, with tank capacities of 132, 165 and 185 gallons, respectively. They are claimed to be economical in operation, even on small production, and a considerable saving in floor space is, of course, achieved. The machines can be supplied for heating by steam, hot water, electricity or gas.

Wilhelm Wache, G.m.b.H., Hamburg, Germany—Sole Agents in the U.K.: I.F.A. Engineering Co., Ltd., 13/17, *Rathbone Street, London, W.1.*

Anti-Scuffing Spray

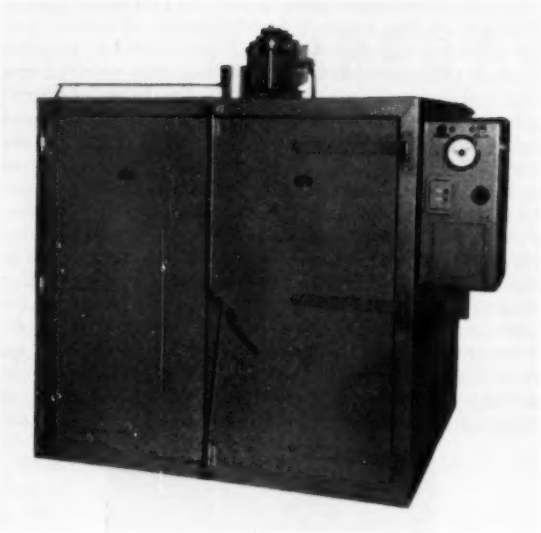
ROCOL, LTD., have recently introduced Anti-Scuffing Spray, in an aerosol pack providing a quick, handy, efficient method of applying molybdenum disulphide lubricant films to metal surfaces in many industries. The spray contains a basis of molybdenum disulphide of particle size best for surface treatments, a bonding resin to effect retention of a film, and a propellant. The vapour is non-toxic, non-corrosive and not harmful or offensive to human beings. The purpose of the spray is the production of a hard bonded lubricating film of molybdenum disulphide on metal or plastic surfaces.

Rocol, Ltd., Rocol House, Swillington, near Leeds.

Electric Ovens

HEDIN, LTD., have re-designed and improved their range of medium capacity electric ovens, so as to incorporate the latest features in oven-building practice. They are designed with vertical airflow for floor-loading, and trolleys and guide rails can be provided to facilitate charging. Double-skin steel construction is employed with fibre-glass insulation, and where it will help transport or erection, any oven can be supplied in sections. Doors are normally double-hinged and fitted with asbestos heat seals. However, when it is important to save floor space, a vertical lifting door, counter-balanced for easy manual operation, can always be provided. In the closed position, this is secured with screw clamps. Internal dimensions fall generally within the range: 5 ft. high × 4 ft. wide × 4 ft. deep, up to 8 ft. high × 8 ft. wide × 8 ft. deep.

The air circulation unit, which may comprise one or



two fans, is placed on top of the oven, where it is out of the way yet readily accessible for maintenance. The elements have heat-resisting, Inconel sheaths, and may be easily withdrawn from behind the vertical air guides on the oven sides, should they require attention. The control gear is housed in a separate cabinet, usually mounted on the side of the oven, where it is clearly visible and readily accessible. Every oven is stringently tested for temperature distribution and airflow before leaving the works. Normal variation is ± 2% of the working temperature.

*Hedin, Ltd., Commerce Estate, South Woodford, London, E.*18.

Lightweight Air Hose

THE introduction of a new lightweight air hose for use with their " bay " L 900 spray gun is announced by Alfred Bullows & Sons, Ltd. This is a rubber hose covered with rayon braid and has a bore of $\frac{1}{8}$ in. It is lighter, more flexible and gives greater ease of handling than the standard type hose : it is also less expensive. Prior to the introduction of the $\frac{1}{8}$ in. hose, it was usual to use $\frac{5}{16}$ in. bore air hose with guns of this type. A comparison between a 10 ft. length of $\frac{1}{8}$ in. hose and connectors and a 10 ft. length of $\frac{5}{16}$ in. hose and connectors shows that the length of smaller hose weighs $5\frac{1}{2}$ oz. as opposed to 25 oz. From the operators point of view, this is a most useful development, since the L 900 spray gun is the smallest and lightest gun in the Bullows range, and the use of the new air hose reduces fatigue and gives exceptional freedom of movement.

Alfred Bullows & Sons, Ltd., Long Street, Walsall, Staffs.

New Magnetic Alloy

THE outstanding magnetic properties of certain alloys in the cobalt-platinum system have been known to metallurgists for many years, but it is only in recent times that the properties of the alloy containing an equal number of atoms of each element (23·3 wt.-% cobalt) have been fully appreciated. Platinax II is the latest development in this field, and is one of the most powerful permanent magnet materials.

After heat treatment by a special process, Platinax II has remarkable physical and magnetic properties, a remanence of about 6,400 gauss, a coercive force of 4,800 oersteds and a BH(max.) of $9{\cdot}2 \times 10^6$ gauss-oersteds being obtainable. Moreover, in the heat treated state the alloy is magnetically isotropic, exhibiting similar magnetic properties in all planes. Apart from the benefit of its exceptional magnetic properties, the use of Platinax II offers a further advantage in that the alloy is comparatively workable before heat treatment and can be machined, rolled and drawn without difficulty, and so lends itself to the manufacture of magnets of complicated shape or extremely small size.

Johnson Matthey & Co., Ltd., 73-83 *Hatton Garden, London, E.C.*1.

Deep Drawn Aluminium Machining Stock

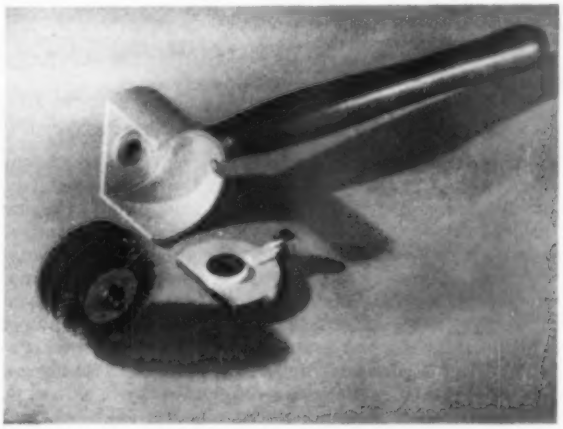
HARVEY ALUMINIUM has extended the production sizes for deep-drawn aluminium machining stock from $2\frac{1}{2}$ in.–4 in. diameter. The new sizes offer cold-finished tolerances to screw machine companies at prices competitive with either hot rolled or extruded bars. Cold-finished tolerances provide an excellent surface finish so that, for ordinary requirements, no machining or additional finishing is needed when the original cross-section of the bar corresponds to that of the finished part.

According to Harvey, the advantages of deep-drawn machining stock are fast cutting, long tool life, good surfaces, true threads, a minimum of finishing operations, consistency in dimension, and material uniformity. It is claimed that deep-drawing the material works the aluminium rod and bar in such a manner that a metallurgical structure is obtained which is homogeneous across the section and throughout the length, and which is particularly conducive to efficient machining.

Harvey Aluminium, 19200 *S. Western Avenue, Torrance, California, U.S.A.*

Abrasive Belt Dresser

A NEW rotary dressing tool for cleaning abrasive belts, is designed to prolong the working life of belts and reduce the number of changes. The Ideal belt dressing tool is calculated to restore full cutting power to clogged



abrasive belts in the shortest possible time, thus speeding production and reducing sanding costs.

The tool is well designed, very simple in construction and comprises an easily-removed triple wire rotary brush, 1 in. wide, mounted in a cast iron casing. The brush is force-fitted onto a special hardened steel pin, which fits into steel bearings inside the case. The casing itself, which is semi-cylindrical, 2¼ in. wide, provides adequate protection for the operator's hands and reduces the danger from flying particles. One side of the casing is detachable for replacement of brushes when necessary: this plate is held in place by a nut. The tool is fitted with a stout handle, 9¾ in. long, with a ferrule at the forward end where it joins the casing.

Finishing Aids and Tools, Ltd., Buckingham Court, 78 Buckingham Gate, London, S.W.1.

New Shape Aluminium Ingot

Aluminium Union, Ltd., the distributors here of Alcan aluminium, have introduced a radically new type of interlocking 50-lb. ingot which is claimed to be safer, easier and faster to handle during transport and by the users. This follows an extensive Alcan programme of development and testing in the field to secure the best ingot shape which would take full advantage of mechanical handling equipment. Alcan regard the new design as the most significant advance in aluminium ingot shape since production of the metal began. They are in the process of converting completely to the new ingot as their standard for the 50-lb. form of 99·5% aluminium, but meanwhile only limited quantities of the new ingot are available.

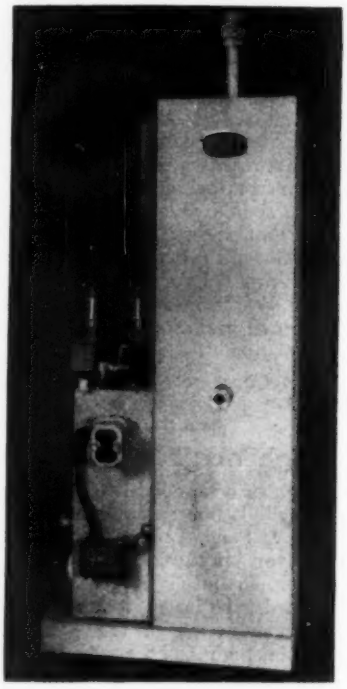
The new design ensures that in strapped bundles the ingots are locked together in the three dimensions, vertical, lateral and lengthwise. Two metal straps serve to secure a neat bundle of 40 ingots, making a convenient 2,000 lb. unit which stands up well to shocks in transit and can be stacked six-high with other bundles to form a stable pile. The straps, which are prevented from slipping by the wasp-waist design of the ingots, can readily be removed. The bundle is then free-standing and stable, and individual ingots can easily be lifted out for handling and furnace charging. Unstrapped bundles or part-bundles can be moved by fork-lift truck. This development will no doubt be welcomed by all who have an interest in the movement, storage or handling of aluminium ingot. The stability of the bundles will contribute to safety and enable better use to be made of shipping and storage space and of mechanical handling equipment.

Aluminium Union, Ltd., The Adelphi, John Adam St., London, W.C.2.

Small Exothermic Gas Generator

In protective atmospheres for use in the heat treatment of metals, it is necessary to avoid the presence of free oxygen and to ensure that the proportions of the oxidising gases—carbon dioxide and water vapour—are controlled at a level sufficiently low to suit the alloy concerned and the temperature of treatment. A compact and economical protective atmosphere generator recently developed by Royce Electric Furnaces, Ltd., has a rated output of 150 cu. ft. of prepared atmosphere per hour, and the whole plant occupies a floor area of less than 3 ft. square. Larger units with capacities ranging up to 2,000 cu. ft. per hour are also available.

The prepared atmosphere, known as exothermic gas, is obtained by the controlled combustion of town's gas. The products of this combustion are cooled to in order separate the excess water vapour and then purified free from sulphur and passed direct to the heat treatment furnace. The volume of prepared atmosphere produced is governed by the degree of combustion permitted in the combustion chamber. With partial combustion, as required, for instance, in the bright annealing of steel, the yield of atmosphere is approximately three times that of the raw gas burnt, and the total electrical consumption is less than 150 W. per 100 cu. ft. of atmosphere. The degree of combustion permitted depends upon the alloy being treated and the temperature of treatment, and is controlled by the ratio of air to gas in the mixture admitted to the combustion chamber. This ratio is easily set by a screw adjustment on an obturator tee on the metering device, and the actual flow of gas and air is indicated on direct reading flowmeters.



The combustion chamber which is lined with high quality refractory is specially constructed with refractory baffles to give the requisite temperature and turbulent flow. To conserve heat and give temperate working conditions, the lining is backed by a wall of thermal insulating bricks, the whole being enclosed within a gas-tight casing. From the combustion chamber the burnt gas passes through a water-cooled collection duct to a heat exchanger which effectively cools the gas, and removes the excess water vapour. Finally, the gases are purified in a vertical desulphurising retort containing iron oxide.

Each unit is completely assembled as a packaged unit on a floor mounting baseplate, and tested before leaving the factory.

Royce Electric Furnaces, Ltd., Walton-on-Thames, Surrey.

CURRENT LITERATURE

Book Notices

NOBLE METAL THERMOCOUPLES

By H. F. Bennett. Second edition. Johnson, Matthey & Co., Ltd., 73–83, Hatton Garden, London, E.C.1.

A SECOND edition of "Noble Metal Thermocouples" has recently been published by Johnson Matthey & Co., Ltd. The contents give a comprehensive survey of the development of noble metal thermocouples, their applications and methods of calibration. The properties of the platinum group metals and their alloys in relation to the problem of temperature measurement are discussed, and information is given on the principal causes of deterioration of thermocouples.

Two new sections have been added to the book. The first of these is "Temperature Measurement in Glass Manufacture." Radiation methods of temperature measurement are employed, but these are not as suitable as the thermocouple for accurate temperature determination in the depth of the melt. Moreover, by employing a well protected platinum : rhodium-platinum thermocouple, the temperature at chosen points of the melt can be continuously recorded and automatic temperature control becomes possible.

The second new section is "Temperature Measurement in the Foundry." This describes the quick immersion technique, which, by employing a suitably sheathed platinum : rhodium-platinum couple and an automatic indicating-recording instrument, provides a rapid accurate and reliable method of determination of the temperature of molten metal.

BENDING ALUMINIUM

46 pp. Information Bulletin No. 24, Aluminium Development Association, 33 Grosvenor Street, London, W.1. 2s.

CONTINUING the series of A.D.A. Bulletins on manipulating practice—earlier ones have dealt with spinning and panel-beating, deep drawing and pressing, forming by rubber die press, and forming by drop stamp—this Bulletin is concerned with the more usual bending operations, but it excludes stretch forming (or stretch bending), and does not deal with the more unusual bending techniques necessary for making special components.

The Bulletin opens with a classification of aluminium and its alloys, primarily as between the non-heat-treatable and heat-treatable groups, and continues with factors affecting the choice of materials for bending or flanging. Brief notes on the bending properties of aluminium, including the important matter of spring back, complete the preliminary pages and lead to the major section of the publication dealing with the bending operations. The operations in question are grouped under sub-headings of : bending sheet and strip ; bending plate ; bending bars and sections ; and bending tubes. Each section includes a table of bend radii for the alloys appropriate to the particular form—sheet, plate, etc.—under discussion.

The Bulletin is addressed mainly to production engineers, designers, draughtsmen, works managers and foremen, but it should also be helpful to operators and apprentices. Sufficient data are given to guide users on the potentialities of aluminium, and on the effective choice of purity or alloy and temper or condition for constructions where bending is required.

Trade Publications

SINCE the foundation of the firm over fifty years ago, rolling mills of all types have constituted the greater part of the production of W. H. A. Robertson & Co., Ltd. In the early days the firm specialised in mills for cold rolling, but over the last twenty years the design and construction of mills for hot rolling sheet, strip, ingots, billets, sections, bars and wire rod has been undertaken. Other products include machines for slitting, trimming, flattening, shearing, swaging, wire drawing, ingot scalping, tube making, etc. A 66-page booklet, reprinted from a series of articles in *British Machine Tool Engineering*, tells the story of the company in terms of its products and the methods used in their manufacture.

"CONTROLLED ATMOSPHERES FOR METALLURGICAL PROCESSES" is the title of a recent publication of the Incandescent Heat Co., Ltd. It takes the form of a reprint of an article by Mr. I. L. S. Golding, Manager of the Gas Atmospheres Division, which appeared in *Metal Treatment and Drop Forging*. The chemical reactions involved in controlled atmosphere heat treatment are discussed and present-day processes and plant for generating special atmospheres are surveyed.

WE have received from George Kent, Ltd., four recent publications. Two of them Nos. 1516 and 1517 are lists of spare parts for Commander instruments, the former being concerned with chart drive units and the latter with mercury in steel temperature measuring units. Of the other publications, No. TP5039 is an article on primary elements for temperature measurement, in which reference is made to resistance thermometers, thermocouples and radiation pyrometers. Publication 2022 discusses the instrumentation and automatic control of open-hearth furnaces, dealing briefly with roof temperature control, flow measurement, fuel/combustion-air ratio control, oil/atomising-steam ratio control, furnace pressure control, checker temperature measurement, furnace reversal, and automatic combustion control based on oxygen determination.

THE temperatures reached in Septre III—the apparatus developed in the Research Laboratory of Associated Electrical Industries, Ltd., to study thermonuclear reactions—are far beyond the range of common means of measurement, and so a spectrographic method had to be adopted. An article discussing this technique appears in the November 1958 issue of *Hilger Journal*, along with a description of the use of a digitised measuring machine for determining stellar declinations.

BARCLAYS BANK D.C.O., which has more than 600 branches in South Africa, has produced a 50-page colour brochure which gives a valuable indication of the opportunities in the Union for the British exporter. Titled "The South African Market," the brochure is

packed with the latest commercial and industrial statistics, charts and notes on the structure and habits of the population. A notable feature in recent years has been the growth of the South African manufacturing industry. The brochure gives details of this expansion and shows the resulting changes in the classes of goods which the country needs to import.

Inland centres are analysed in a series of density population charts and the developing demand for capital equipment and consumer goods is examined. Exporters are advised that the European as well as the non-European population is increasing at a comparatively high rate and that the purchasing power of the Bantu is rising steadily. But the brochure warns that in the long run South Africa will tend to import fewer consumer goods and more capital goods. The market prospects for such goods are set out.

Copies of the brochure may be obtained free of charge on application to the Intelligence Department, Barclays Bank D.C.O., 54, Lombard Street, London, E.C.3.

In keeping with the policy of devoting its pages to matters of interest in the heat treatment and metallurgical field, including items not coming within the scope of the company's own productions, the December 1958 issue of *The Wild-Barfield Heat-Treatment Journal* contains an article, reprinted from *Platinium Metals Review*, on the care of platinium thermocouples. Other features deal with control gear as applied to electric furnaces, the Model 912 vacuum fusion gas analyser, and the Model 2904 resistance heated vacuum furnace.

The application of tungsten carbide tips to circular saws has been described as one of the most revolutionary steps ever made in the field of high speed sawing, in that it combines tips made of one of the hardest materials with a relatively soft and flexible saw disc to withstand the normal shock loading experienced in workshop practice. An illustrated leaflet has recently been issued by Firth Brown Tools, Ltd., describing their Speedicut Mitia carbide tipped saws, which are suitable for cutting plastics, wood, asbestos, non-ferrous metals, graphite,etc.

The vacuum melting plant which has been used successfully by William Jersop & Sons, Ltd., for the production of the Hylite range of titanium alloys and the Vacumelt brand of vacuum melted sheets, is now increasing its scope by the production of zirconium and zirconium alloys. A new information sheet (No. M840) presents information on the mechanical and physical properties of zirconium, and compares the corrosion resistance of titanium, molybdenum-bearing 18 : 8 stainless steel, and zirconium, in a number of media.

A return to the theme of design is made in the latest issue of *Enchiridion*, the Firth Vickers Stainless Steels publication, in which particular attention is paid to the design of domestic appliances. This is especially important in view of a recent report that the buyer of a large store stated that almost 75% of his stainless steel domestic articles came from abroad. Other features in this issue deal with design in catering, the use of stainless steel in cigarette manufacture, heat resisting steel for blast furnace tuyère blowpipes, and the shearing of stainless steel.

Selling must nowadays be pursued with vigour and imagination, and an important feature of any sales campaign is the publicity and advertising that supports it. Just how this is done is told in some detail in a new book—The Technical Advertising Agency, what it is, what it offers—issued by J. Peers & Associates, specialists in technical and industrial publicity, of Summit House, 1–2, Langham Place, London, W.1. The book is free, on application, to all executives interested in increasing the impact of their own publicity campaigns. It discusses authoritatively the many aspects of industrial and technical advertising and tells in detail how the J.P.A. organisation goes to work on behalf of its clients, many of whom are world-known and number among the largest industrialists in the U.K.

We have received from Northern Aluminium Co., Ltd., a folder describing Noralduct—solid aluminium sheet having internal systems of passages and ducts. It is particularly suitable for heat transfer equipment and, as the integral passages can follow almost any complex continuous pattern that can be drawn on paper, there are many other possibilities. The folder includes lists of the present uses of Noralduct and some of the possible ones, together with a short description of its manufacture, and a guide to its present tolerances and manufacturing limits.

Books Received

"The Heat-Treatment of Steel," by E. Gregory and E. N. Simons. Second Edition. 381 pp. inc. index and numerous illustrations. London, 1958. Sir Isaac Pitman & Sons, Ltd. 35s. net.

"Fast Reactions in Solids," by F. P. Bowden and A. D. Yoffe. 164 pp. inc. author and subject indexes and numerous illustrations. London, 1958. Butterworths Scientific Publications. 40s. by post 1s. 6d. extra. The American edition of this book is published by Acedemic Press, Inc., New York, at $7.00.

Proceedings of the Eighth Meeting of the International Committee of Electrochemical Thermodynamics and Kinetics, Madrid, 1956. 497 pp. London, 1958. Butterworths Scientific Publications. 95s. By post 2s. extra.

"Using Steel Wisely," by L. Aitchison and W. I. Pumphrey. 241 pp. inc. 88 illustrations, and index. London, 1958. Macdonald and Evans, Ltd. 44s.

"A Dictionary of Metallurgy," by A. D. Merriman. 401 pp. inc. numerous illustrations and tables. London, 1958. Macdonald and Evans, Ltd. 126s.

"Crushing and Grinding." A Bibliography. 425 pp. inc. subject and name indexes. London, 1958. H.M. Stationery Office. 35s. net.

"Symposium de Métallurgie Spéciale." June 1957. Institut National des Sciences et Techniques Nucléaires. 128 pp. Paris, 1958. Presses Universitaires de France.

"Anti-Corrosion Manual." 260 pp. London, 1958. Corrosion Prevention and Control (Scientific Surveys, Ltd.).

"Zone Melting." By W. G. Pfann. 236 pp. inc. numerous illustrations and index. New York and London, 1958. John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 60s. net.

"Ceramic Fabrication Processes." Edited by W. D. Kingery. 235 pp. inc. index. Massachusetts, New York and London, 1958. The Technology Press of Massachusetts Institute of Technology, John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 76s. net.

Electrical Aids in Industry *Data Sheet* **No. 3**

Induction Heating - 2

The broad principles involved in the use of induction heating for melting and processing metals have already been dealt with in this series (Data Sheet No. 2). In order to make a critical examination of its possibilities, however, the potential user should be aware of certain technical factors which must influence his decisions.

Induction heating, of course, demands the use of alternating current which is available from the public supply at a frequency of 50 cycles per second. Higher frequencies, however, are desirable for certain applications and can be obtained by means of the appropriate conversion equipment. Frequencies can therefore be considered in three categories:

Mains Frequency
(direct from mains)—50 c.p.s.

Medium Frequency
(machine generator)—50-10,000 c.p.s.

High Frequency
(electronic generator)—up to about 2,000,000 c.p.s.

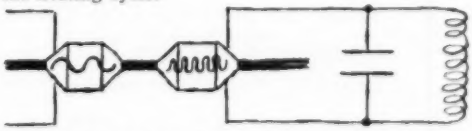
Mains Frequency

This needs no conversion equipment; it is particularly suitable for melting large pieces of scrap and, owing to the vigorous stirring forces produced, is excellent for alloy making. It has the merit of low initial cost compared with the high frequency method of melting, but is not so suitable for the production of high grade steel. Mains frequency induction heating is also useful for stress-relieving of welds in pipes and vessels, heating of chemical vessels, pipelines, injection moulding machines and press platens.

A typical example of the use of mains frequency is the coreless induction melting furnace which can be connected direct to the public 3-phase supply. Such a furnace rated at 120 kW, with a holding capacity of 2,240 lb., will give a throughput of 5,000 lb. per hour of hot cupola metal superheated from 1,350°C to 1,450°C.

Medium Frequency

Motor generators ranging from 10 kW to 1,500 kW or more at frequencies up to about 10,000 c.p.s. are widely used for heating for forging, melting from 100 lb. to 10 tons, hardening, annealing, etc. A bank of capacitors maintains a high power factor during the heating cycle.



Another form of generator for frequencies of 1 to 2 kc.p.s. and powers around 250 kW, useful for forge heating and melting high temperature aircraft alloys, is a 6-anode steel tank mercury arc inverter.

High Frequency

Metal hardening and metallurgical processing are best handled by high frequency induction (up to about 2,000,000 c.p.s.), particularly when a very thin case is required or when the section of the workpiece is too small to heat satisfactorily at medium frequency. These high frequencies are produced either by an electronic h.f. generator or a mercury-gap h.f. generator; high frequency induction can deal efficiently with such jobs as hardening lawnmower cylinders and cutters, bars and axle shafts.

The choice of frequency depends upon the metallurgical requirements and the size of the component to be treated. The following table gives the practical relationship between size and frequency, and may be used as a guide to the choice of generator, subject to metallurgical considerations.

Optimum Value

FREQUENCY C.P.S.	3,000	10,000	500,000	2,000,000
MIN. DEPTH OF HARDNESS POSSIBLE	.060 in.	.040 in.	.020 in.	.010 in.

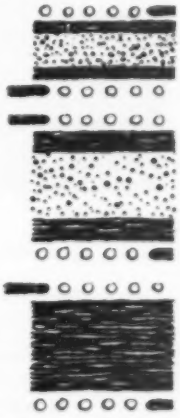
Practical Values

MIN. DEPTH HARDNESS EXPECTED	.150-.200 in.	.100-.150 in.	.030-.050 in.	.015-.030 in.
MIN. DIA. SURFACE HARDENING THIN CASE	2" & over	1" to 3"	½" to 2"	¼" to ½"
MIN. DIA. SURFACE HARDENING DEEP CASE	2" & over	2" & over	1" & over	not suitable
MIN. DIA. THROUGH HARDENING	1" & over	½" to 2"	¼" to ½"	not suitable

These are of course very approximate since they also depend on metallurgical considerations.

Power required for H.F. Induction Hardening

The high frequency power required per sq. in. of hardened surface depends upon the amount of metal behind the surface. Higher powers and shorter heating cycles are necessary for thin cases and when the thickness of metal behind the surface is small.


0.03" to 0.04" requires 1 sec. or less at 10 kW or more per sq. in.
0.1" to 0.2" with a large mass of metal behind the surface, requires 10-60 secs. at 2 kW per sq. in.
Through hardening requires 10-12 kWh per lb.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association. Excellent reference books (8/6, or 9/- post free) are available on electricity and productivity—"Induction & Dielectric Heating" is an example.

E.D.A. also have available on free loan a series of films on the industrial use of electricity. Ask for a catalogue.

Issued by the Electrical Development Association, 2 Savoy Hill, London, W.C.2 6515

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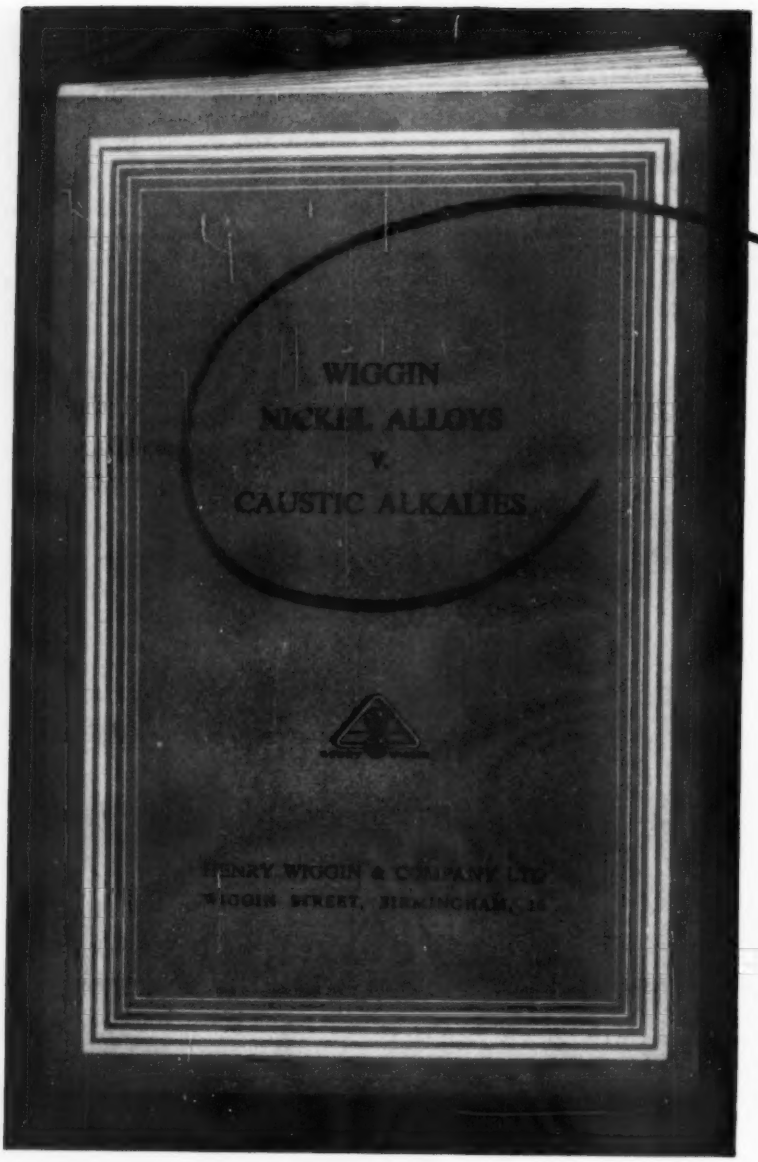

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LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS
FEBRUARY, 1959 Vol. LIX, No. 352

Rapid Determination of Niobium in Stainless Steel

By R. St. J. Emery
Wilmot Breeden, Ltd.

A spectrophotometric procedure is described whereby the niobium content of 18-8 type stainless steels can be determined in an hour and a half. Details are given of the method of separation of the niobium, and of the precautions to be taken in the presence of interfering elements.

RECENT advances in methods for the analysis of stainless steels have made a more rapid method for the determination of niobium a matter of some urgency. Gravimetric methods for niobium are notoriously slow, and investigation of a photometric method using the reduced niobium thiocyanate complex in an organic medium seemed the most promising way to tackle this problem. If such a method could be applied without a preliminary separation of the niobium with cupferron, tannic acid or other organic reagent, and subsequent fusion, the time saving would be considerable.

The thiocyanate spectrophotometric method of analysis for niobium has been thoroughly investigated in recent years,[1-3] and has been applied to the analysis of minerals and ores.[4,5] In adapting the method to stainless steels, use has been made of the phase separation which occurs when the acid concentration exceeds 1·4 moles per litre with acetone as the organic medium. A separation of the upper organic phase containing the coloured niobium complex and the lower acid layer containing the majority of the other cations removes directly all the iron, chromium and nickel.

Other metals such as tungsten, titanium, cobalt and molybdenum give coloured complexes with thiocyanate. Molybdenum was found to have an unstable colour which disappears during the separation. Tungsten and titanium if present may be allowed for by means of correction graphs. The proposed method is most suitable for steels where these metals exist only in small quantities as impurities.

The Unicam S.P.500 spectrophotometer was used and readings taken at 383 mμ. The method, however, may be adapted for the Spekker absorptiometer, using Wratten No. 2 and Chance OV1 filters to isolate the line 405 mμ from the mercury vapour lamp.[5]

The time taken for an individual estimation is about an hour and a half, with a corresponding reduction when samples are analysed in batches.

Method

Solutions Required

Ammonium Thiocyanate (20%)—Dissolve 20 g. ammonium thiocyanate in 100 ml. acetone and add 5 ml. chloroform. Make a fresh solution daily.

Stannous Chloride (10%)—Dissolve 50 g. stannous chloride in 50 ml. conc. hydrochloric acid by gentle heating. Make up to 500 ml. with water and store under hydrogen.

Sulphuric Acid (50/50)—Add cautiously 500 ml. conc. sulphuric acid to 500 ml. water, cool and dilute to 1 litre.

Procedure

Weigh, accurately, 0·10 g. of drillings into a 250 ml. conical beaker, add 40 ml. water and 16 ml. sulphuric acid. Heat gently until reaction ceases, oxidise with a few spots of nitric acid and fume gently. Transfer to a 100 ml. graduated flask, washing the beaker with 50/50 sulphuric acid and make up to the mark with 50/50 sulphuric acid. Separation of the niobium is effected in the following manner.

(1) Into a separating funnel, of approximately 125 ml. capacity, measure in the following order :—
- (*a*) 4 ml. hydrochloric acid,
- (*b*) 6 ml. stannous chloride solution,
- (*c*) 15 ml. ammonium thiocyanate in acetone,
- (*d*) 5 ml. of the solution of the sample.
- (*e*) Agitate and cool for two minutes, allow to settle, and run off the acid layer.

(2) To the acetone layer in the separating funnel add :
- (*a*) 4 ml. hydrochloric acid.
- (*b*) 4 ml. stannous chloride solution,
- (*c*) 6 ml. ammonium thiocyanate in acetone,
- (*d*) 5 ml. 50/50 sulphuric acid.
- (*e*) Cool, agitate and separate as before.

(3) Take a 25 ml. graduated flask and measure into it :
- (*a*) 3 ml. hydrochloric acid,
- (*b*) 1·5 ml. stannous chloride solution,
- (*c*) 1 ml. ammonium thiocyanate in acetone.

Run the acetone layer from (2) into the graduated flask, swilling out the separating funnel with a little acetone, make up nearly to the mark with acetone, cool, and finally adjust the volume with acetone.

A 5 ml. quantity of 50/50 sulphuric acid should be run through these processes as a blank for reagents.

Use a 1 cm. cell and read the density at 383 mμ with acetone in the reference cell, deduct the blank and read the niobium content on the graph. If the sample contains molybdenum, the final solutions should be allowed to stand for 15 minutes to allow the molybdenum colour to decompose.

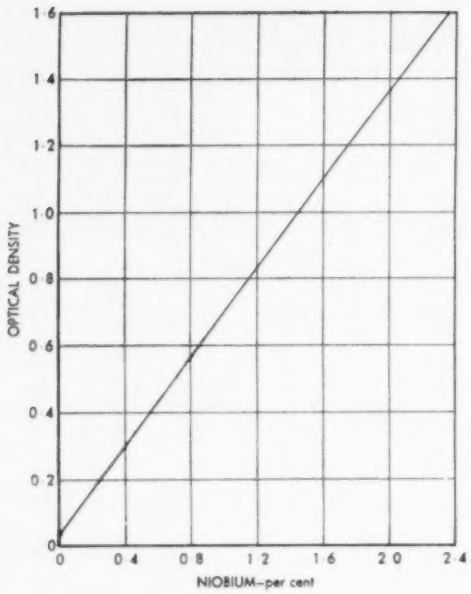

Fig. 1.—Relationship between density and niobium content at 383 mμ.

Standardisation

Weigh 0·0714 g. pure niobium pentoxide into a platinum crucible and add 1 ml. of water and 3 ml. hydrofluoric acid, heat until all is in solution, add 6 ml. of 50/50 sulphuric acid, and fume gently. Transfer to a 500 ml. graduated flask with successive quantities of 50/50 sulphuric acid and make up to the mark with the same acid. Then 1 ml. of this solution will contain 0·0001 g. of niobium.

Weigh five 0·10 g. quantities of pure iron into 250 ml. conical beakers; make no addition to the first, to the second add 4·0 ml., to the third 8·0 ml., to the fourth 16·0 ml., and to the fifth 24·0 ml. of the niobium solution. In the respective flasks the niobium will be 0·0%, 0·4%, 0·8%, 1·6% and 2·4%. Add 40 ml. water to each and successively smaller amounts of concentrated sulphuric acid to bring the total of the latter to 16 ml. Heat gently until the reaction ceases, oxidise with a few drops of nitric acid and fume gently. Transfer to a 100 ml. graduated flask, washing the beaker with 50/50 sulphuric acid and make up to the mark with 50/50 sulphuric acid.

Proceed with the separation of niobium and the spectrophotometry as outlined for the method, plotting the results on a graph (see Fig. 1).

Correction Graph for Titanium

The titanium content of niobium-stabilised stainless steels is usually extremely low, but its complex has a high absorption at 383 mμ, 0·1% of titanium being roughly the equivalent of 0·14% of niobium. It is therefore advisable to check the titanium content of the steel by the peroxide method in all cases. Titanium imparts a bright golden colour to the final solution; the niobium complex itself is a pale straw colour.

Weigh 0·05 g. of pure titanium into a small beaker, add 10 ml. of hydrochloric acid and heat gently till it is in solution. Cool and adjust the volume to 500 ml. with

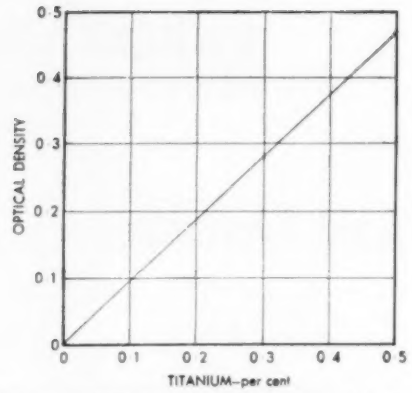

Fig. 2.—Titanium correction graph (383 mμ).

50/50 hydrochloric acid. Then 1 ml. of the solution will contain 0·0001 g. of titanium. Proceed as in the standardisation procedure, adding aliquots of this solution to weighed quantities of pure iron, to give a correction graph covering titanium up to 0·5%. (Fig. 2).

Correction Graph for Tungsten

Although the tungsten content of a normal 18–8 stainless steel is usually very low, this element has a comparatively high absorption at 383 mμ, 1% of tungsten giving an absorption equivalent to approximately 0·13% of niobium, and a correction graph for this element is advisable.

Weigh 0·0632 g. pure tungsten trioxide and dissolve in a little sodium hydroxide solution and adjust to 500 ml. with 50/50 sulphuric acid. Then 1 ml. of this solution will contain 0·0001 g. of tungsten. A correction graph for tungsten may then be constructed for up to 2% of tungsten in a similar manner to the standardisation procedure. (Fig. 3).

Discussion

No difficulty should be experienced in obtaining a clear solution of the samples provided that the period of fuming is not unduly prolonged, only silica is insoluble. Hydrolysis of the niobium is prevented by the subsequent use of 50/50 sulphuric acid. Tests on the precipitated silica showed its niobium content to be negligible.

The phase separations are a very effective means of removing iron, chromium, nickel and manganese. The presence of a small amount of chloroform in the acetone solution of thiocyanate makes the line of demarcation very definite. Four solutions from stainless steels after the separations were combined and analysed. No nickel or chromium could be detected and only 5 μg. of iron.

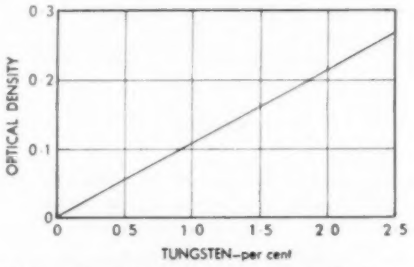

Fig. 3.—Tungsten correction graph (383 mμ).

TABLE I.—INFLUENCE OF TIME ON OPTICAL DENSITY OF THE NIOBIUM COMPLEX

Time (hr.)	Optical Density		
	Sample A	Sample B	Blank
½	0·620	1·125	0·055
1	0·630	1·130	0·045
3	0·640	1·150	0·064

Interference

The method is intended for straight niobium-stabilised steels of the 18% chromium 8% nickel type, which usually contain only small quantities of residual metals as impurities. Titanium, tungsten, vanadium, cobalt and molybdenum give coloured complexes with thiocyanate.

Titanium gives the most serious interference and may be corrected for. Tungsten and vanadium behave similarly but they have seldom been found in sufficient amount to affect the result appreciably.

Cobalt, if present in alloying quantities, will produce the blue cobalt complex, but its maximum absorption lies around 600 mμ. As a residual element it has no effect.

Molybdenum, initially, forms the familiar orange complex, but this is unstable and decomposes during the separations. Experiments showed that if 30 minutes were allowed to elapse between the time of making the first separation and reading the optical density, all colour due to molybdenum disappeared.

The B.C.S. standard stainless steel No. 246, which has been used for reproducibility test, contains 2·89% of molybdenum, and the results given agree with the theoretical absorption obtained from the standard niobium solution.

Stability

The niobium complex under these conditions is reasonably stable: typical figures are shown in Table I. Over a period of three hours the density shows a slight increase, whilst the blank firstly decreases slightly and then shows a slight increase. It is best, therefore, to standardise the procedure by taking the readings within 15–20 minutes of obtaining the final solutions. This, incidentally, also makes sure that the precaution in the presence of molybdenum is taken.

The final solution is, essentially, a mixture of concentrated hydrochloric acid and acetone. To avoid fumes in the spectrophotometer which might give erratic results, the cells should only be filled to two-thirds their capacity and should be covered.

Results

The reproducibility of the results was checked over a period of some months, using the B.C.S. standard containing 0·82% of niobium, a sample of this steel being run through together with any samples containing niobium. The figures obtained are shown in Table II:

TABLE II.—REPRODUCIBILITY OF THE METHOD OVER A PERIOD OF SOME MONTHS (B.C.S. STEEL No. 246)

Niobium Present (%)	Niobium Found (%)
0·82	0·85
	0·80
	0·86
	0·81
	0·80
	0·82
	0·81
	0·82
	0·84
	0·82
	Average 0·82

they show an average content of this steel of 0·82% niobium and an average variation of 0·015%.

The gravimetric process previously used was selected to give the figures within a reasonable time, and an absolutely pure precipitate of Cb_2O_5 could not be guaranteed. It was found, however, that in the majority of cases gravimetric and spectrophotometric methods agreed quite well, with an average tendency for gravimetric figures to be high.

Conclusions

By using the thiocyanate in acetone spectrophotometric method, niobium in stainless steels of the 18–8 type can be determined within ninety minutes of receiving the sample, with satisfactory reproducibility.

The coloured niobium complex is produced in conditions of high acidity giving a phase separation which is used to extract the niobium from the bulk of the constituents of the steel. Special precautions can be taken in the presence of certain residual elements.

Acknowledgment

The author wishes to thank Messrs. Wilmot Breeden, Ltd., for permission to publish this paper.

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CIBA Fellowship Trust

THE CIBA Fellowship Trust has been founded for the purpose of improving and increasing the interchange of ideas between scientists in the United Kingdom and on the Continent. Several Fellowships will be awarded for tenure during the academic year 1959–1960 at continental universities or institutions for research in chemistry, physics or some other allied scientific subject. They will be awarded to graduates of Universities situated in the United Kingdom of Great Britain and Northern Ireland or in the Republic of Ireland, or to members of those Universities graduating this year. It is anticipated that some Fellowships will be awarded to recent graduates and other Fellowships to candidates who have already taken their Ph.D., or who have already spent some time in industry.

The basic award for Fellows who have already undergone training in research and wish to continue post-doctorate studies, will be £800 per annum plus allowances including cost-of-living and children's allowance. For candidates who have obtained a first degree in science and wish to undergo training in research, the basic award will be £500 per annum plus allowances. Further details are available from the Secretary of the CIBA Fellowship Trust, CIBA (A.R.L.) Limited, Duxford, Cambridge.

Wild-Barfield Equipment for U.S.

Some months ago, Wild-Barfield Electric Furnaces, Ltd., announced that an order had been received for mains frequency induction heated aluminium holding furnaces valued at approximately $300,000 from a large organisation in the United States. It is now stated that a further order for similar 750 lb. capacity equipments has been placed by the same firm.

Exhibits of Metallurgical Interest at the Physical Society's Exhibition

The exhibits at the Physical Society's annual exhibition of scientific instruments usually include a number of interest to workers in the metallurgical field. This year was no exception, and in this issue we begin a short series of reviews in which such items will be described.

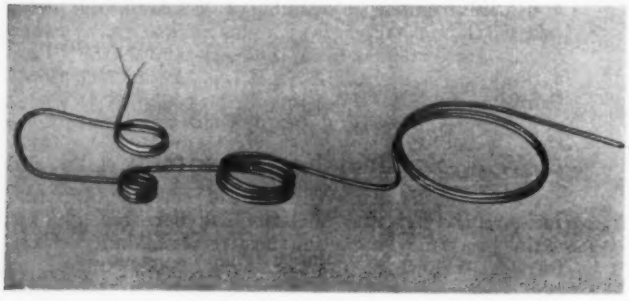
Integral-Sheath Thermocouple

THE integral-sheath thermocouple exhibited by the Baker Platinum Division of Engelhard Industries, Ltd., was developed in order to satisfy a requirement for a high-temperature precious metal thermocouple assembly, which is both flexible and of small diameter. The assembly comprises an outer, flexible metallic sheath having an external diameter of approximately $\frac{1}{16}$ in., surrounding two wires comprising the thermoelements. The thermoelement wires are insulated from one another and from the sheath, by means of a compressed pure oxide refractory powder, and the resulting assembly is flexible enough to permit being formed round a diameter equal to four times that of the assembly, without damage.

Amongst the advantages of this type of assembly, are those of small dimensions and flexibility, and, moreover, the assembly is completely resistant to thermal shock, to which more conventional assemblies comprising thermocouple insulators and outer refractory sheaths are particularly prone. The integral-sheath couple has already found application in at least one type of high temperature nuclear test loop, where the requirements of flexibility and small dimensions precluded the use of conventional assemblies.

A modified assembly of this type is already under development, and consists of an outer metallic sheath (which in addition comprises one element of the couple) surrounding a centrally located single wire which comprises the second element. This co-axial type, also insulated with a compressed pure oxide refractory powder, is expected to have an external diameter of the order of $\frac{1}{32}$ in.

The twin-wire type is currently available in several forms. The Type W. 7/B is specially designed for use in nuclear engineering work, the sheathing alloy and thermoelement materials being resistant to irradiation. It may be used up to 1,600° C. in inert or reducing atmospheres only. The Type W. 7/C is similar, but economy is effected by using a pure nickel sheath for the "lead-out" in cooler zones. Types W. 7/D and W. 7/E are suitable for use at temperatures up to 1,600° C. under oxidising conditions, but are not suitable for use under irradiation. The former has the precious metal sheath and the latter precious metal for the hot zone and a pure nickel "lead-out" sheath intimately bonded to it. Type W. 7/F is similar to Type W. 7/D in respect of thermoelement materials, but is provided with a grain-stabilised S.R. 10 alloy sheath, which is highly resistant to grain growth and deformation at high temperatures.

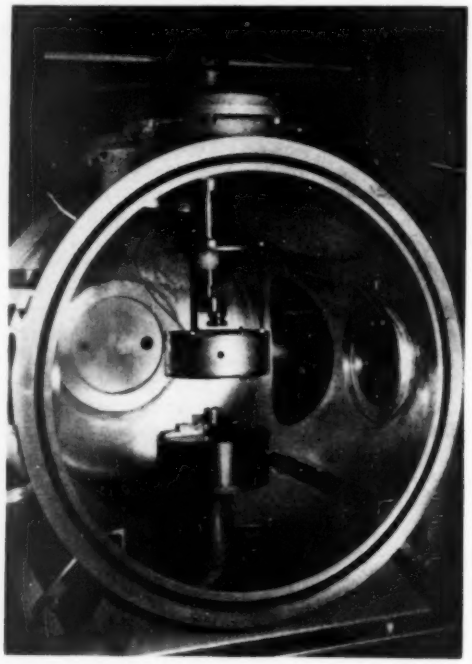


Courtesy of the Baker Platinum Division of Engelhard Industries, Ltd.

Integral-sheath thermocouple bent to show flexibility.

Electron Beam Welding

The process of electron beam welding, carried out in a vacuum of less than 10^{-4} mm. Hg., has proved to be an ideal process for flux-free welding of metals particularly susceptible to oxidation difficulties. One typical application is the capping of nuclear fuel element cans. This development is based on the work of J. A. Stohr



Courtesy of Edwards High Vacuum, Ltd.

Close-up of electron beam welding chamber.

Courtesy of Baldwin Instrument Co., Ltd.

Self-standardising Atomat beta ray thickness gauge with operator's remote control unit.

at C.E.A., Saclay, France, and equipment utilising the technique is manufactured by Edwards High Vacuum, Ltd., under licence to Brit. Pat. Appl., 1962/57. The apparatus exhibited on the Edwards stand is designed for maximum flexibility when carrying out research work on electron beam welding, the work chamber being amply supplied with viewing windows and ports for the introduction of the electron gun and internal handling mechanisms.

In operation, the tungsten filament of the electron gun emits electrons which are accelerated to the work by a high voltage applied between the electron gun and the work, which is at earth potential. The electron beam is electrostatically or magnetically focused, and in this way high intensity localised heating can be obtained on the workpiece by the correct choice of electron spot diameter. The intensity of heating is controlled by alteration of the filament current and applied high tension.

Welding is carried out by moving the work—which is mounted on a turntable beneath the stationary electron gun—with respect to the focused beam of electrons. By this means, welding diameters of up to 6 in. can be obtained. Varying work lengths are accommodated by utilising the combined adjustments of the electron gun and turntable. The power for welding is supplied from a high tension control unit capable of delivering 20 kV. at 100 mA. which incorporates a variable pulsing unit.

Thickness Measurement

Several examples of Atomat thickness gauges based on atomic radiation techniques were featured on the stand of the Baldwin Instrument Co., Ltd. The basic electronics of the Atomat backscatter thickness gauge are identical with those in the standard transmission gauge, but the measuring head is designed in such a way that only one side of the material need be accessible. It is necessary, however, for the other side to be backed with a substance having a substantially different density and atomic number, e.g. rubber on a steel calender bowl, lacquer on zinc, etc.

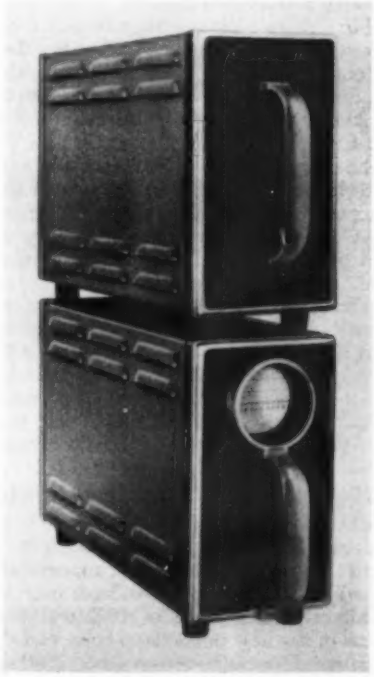
To meet the need for automatic thickness control of products produced on high speed machines, such as metal foil rolling mills, the fast responding Atomat has been developed. The maximum speed of response of the standard instrument is of the order of 0·1 sec., but by using special low capacity head cable, this figure can be reduced to 0·04 sec. It will be seen from this that the gauging and automatic rejection of drawn sheets is possible even when they are presented to the measuring head for only a fraction of a second.

Another exhibit was a standard beta gauge to which had been added a new type of automatic standardising unit designed to maintain the measuring instrument in close accuracy. The standardising unit is available for use with existing Atomats.

Among the accessories were a phototransistor-actuated limit controller, and a C frame housing the radioactive source and ionisation chamber: the frame can be withdrawn from the measuring position by hand or pneumatically.

Ultrasonic Flaw Detection

The twin channel flaw alarm shown on the Kelvin & Hughes stand can be used in conjunction with the Mark 5F and 5AF ultrasonic flaw detectors to register automatically the presence of flaws in a specimen under test. Both these units have similar basic specifications, and will operate with probes fitted with quartz or barium titanate transducers. The Mark 5F detector is a multi-frequency instrument designed specifically for



Courtesy of Kelvin & Hughes (Industrial), Ltd.

Twin channel flaw alarm in operating position with Mark 5F ultrasonic flaw detector.

use in production units, and for laboratory investigation where this flexibility is invaluable, and where the applications involved can adequately be met with probes having twin or common transmitter receiver transducers. The Mark 5AF is a single frequency instrument available for 1½, 2½ or 5 Mc./s. operation. A specially developed amplifier is incorporated to give optimum performance when used with probes having single, twin or common transmitter receiver transducers. This facility for permitting all three normal methods of manual ultrasonic examination to be applied enables complete investigations to be made, and simplifies ultrasonic inspection procedures.

The twin-channel flaw alarm is so designed that it registers only such flaws as occur within the duration of a "gate." The width of this "gate" and the delay between transmission pulse and the start of the gate are continuously between 2 μ.sec. and 3,500 μ.sec. Separate channels facilitate the simultaneous examination of two regions of a specimen, and, if necessary, these may overlap. The sensitivity level for operation of the flaw alarm unit is also adjustable.

Monitoring Washing Processes

The Griffin-Raleigh Elution Bridge, shown by the Griffin-George Group is an instrument designed primarily for monitoring washing processes in transistor production and in the electroplating industry. A conventional Wheatstone bridge network, employing conductivity cells as two of the arms, is arranged so that the out-of-balance current may be amplified in a high-gain transistor amplifier.

One of the cells is connected in the influent line to an elution vessel from which the effluent passes through the second cell. On passing the washing fluid through the empty system a deflection is observed on a moving coil instrument. The flow is continued until a constant deflection is obtained, whereupon the bridge is balanced to zero deflection. By this means the effects of temperature variations, carbon dioxide absorption in the bath, and difference in cell constants are automatically compensated for. On introducing the work to be washed into the elution vessel, a deflection is again observed, and washing is continued until the deflection falls to zero or to a predetermined low value indicating an acceptable level of chemical cleanliness. One of the cells incorporated in each instrument is of known constant value, and the bridge may therefore also be used for the accurate calibration of conductivity cells without the need to use standard solutions. The network is supplied with low-voltage alternating current from an internal source, and the amplifier gain may be varied to suit ambient conditions. The bridge is mains operated.

World Science on Show

A NEW type of exhibition is to be held at Olympia in October. Science—in all its aspects—is to be put on show—both to the specialist and the public. The International Scientific Research Exhibition is being organised to illustrate the story of scientific achievement; to demonstrate the influence scientific development plays in our daily lives; and to explain the promise scientific discovery and research holds for the future. For the first time universities are being encouraged to take part in a public exhibition so that they can make known the very important part they are playing in modern technical and scientific research in all fields.

The scope of the exhibition will be international, and the Grand Hall at Olympia will become a window on the world of international science. Four main themes have been chosen as the pattern for the exhibition: Health and Food—Materials—Transport and Communications—Power and Industry. The visitor to Olympia will be able to start from a point on the Avenue of Discovery and follow a piece of research from the point where it was an idea in somebody's mind through the various stages of development to the finished product, representing a contribution to civilisation.

Kanigen Plating Facilities Extended

As a result of a substantial increase in the U.K. demand for Kanigen plated components, Albright & Wilson (Mfg.), Ltd., the sole U.K. licensees, announce this month that two additional plating tanks have been installed in their Kanigen plating plant at Oldbury, Birmingham. Dimensions of the new tanks have been varied, so that a greater range of components can be handled speedily. Whilst previous plating tanks have been 3 ft. cube, of the new tanks now brought into commission, one is 6 ft. in depth and 2 ft. in diameter, whilst the other is 3 ft. in depth, 4 ft. long and 2 ft. wide.

Kanigen chemical nickel plate is a nickel-phosphorus alloy containing about 8% phosphorus. It has low porosity and is hard (1,000 V.P.N. after heat treatment) and corrosion- and wear-resistant. On ferrous materials the plate prevents contamination of liquids by iron from pumps, pipework and containers. Expensive alloys can often be replaced by Kanigen-plated steel or aluminium. Kanigen is recognised both by the Ministry of Supply and by the Air Registration Board, by whom it has been approved under D.T.D. 900/4505 and A.I. 5112/57, respectively.

An E.D.A. Newsletter

"ELECTRIFIED PRODUCTION" is the title of a new quarterly illustrated four page newsletter prepared by the Electrical Development Association, and intended for distribution by the Electricity Boards to selected industrial consumers in their areas. The first issue is prefaced by a message from Lord Chandos, immediate Past President of E.D.A., in which he says: "There is no single industrial concern, whether large or small which has all the 'know-how' of electrification, and there is no other publication in this country devoted solely to industrial electrification. This modest newsletter does not aspire to fill the gap completely but, within its bounds, it hopes at least to suggest new, electrical, solutions to production problems, and to indicate the sources of further information. Above all it hopes, by putting forward ideas, to stimulate other ideas and to earn the right to be read even by those whose spare time is small."

The newsletter also contains several brief notes on specific applications of electricity to industry, and an account of the electrification of a Stoke-on-Trent pottery. Copies can be obtained either from Electricity Boards, or direct from the British Electrical Development Association, 2, Savoy Hill, London, W.C.2.

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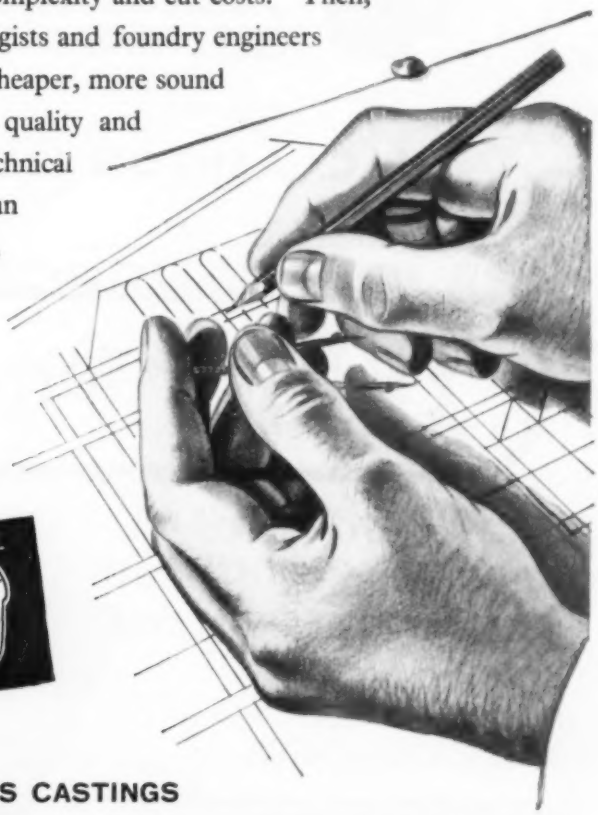

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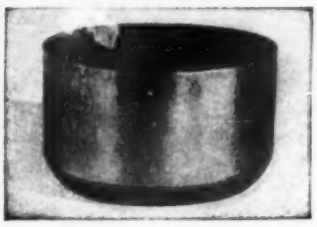

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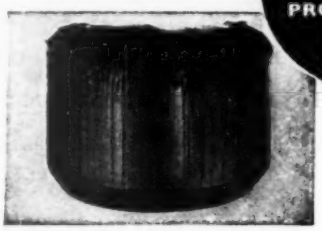

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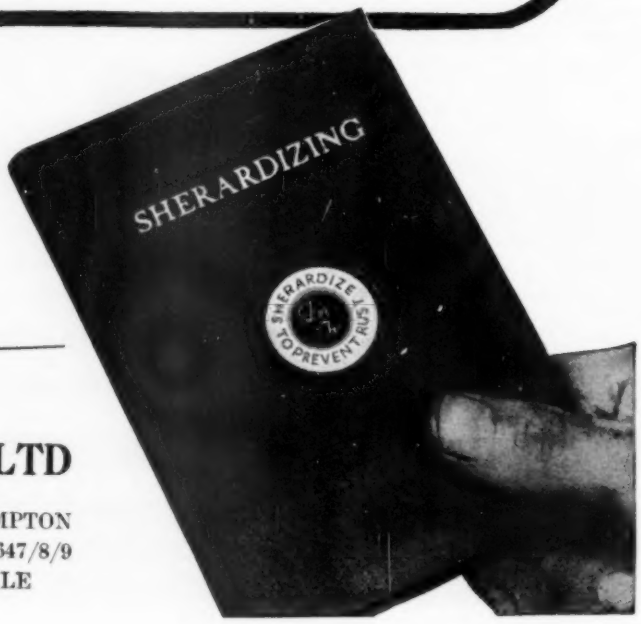

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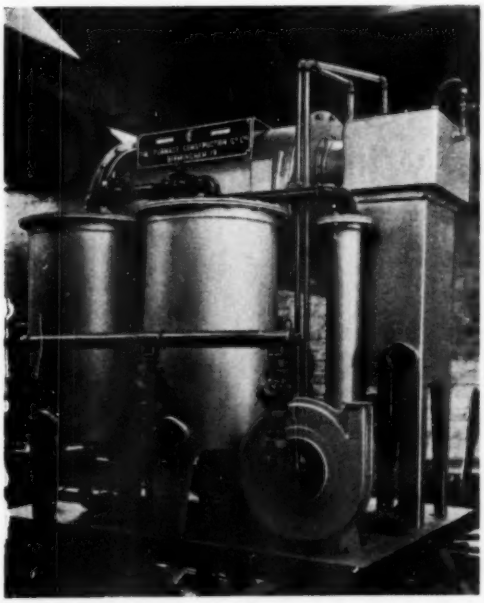

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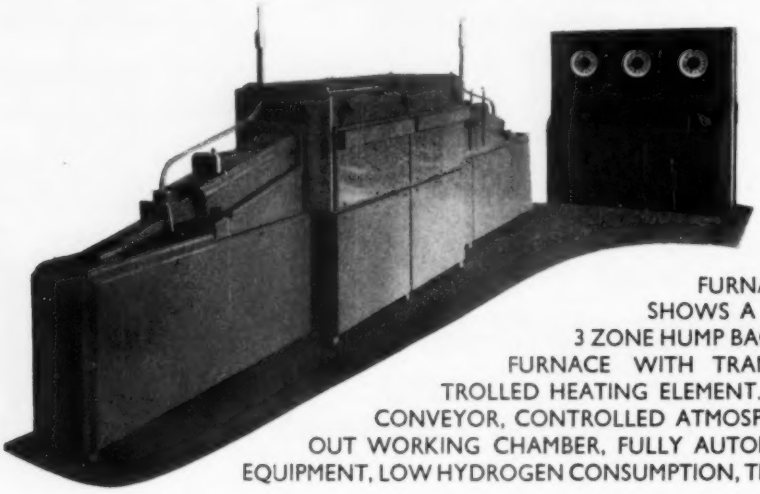

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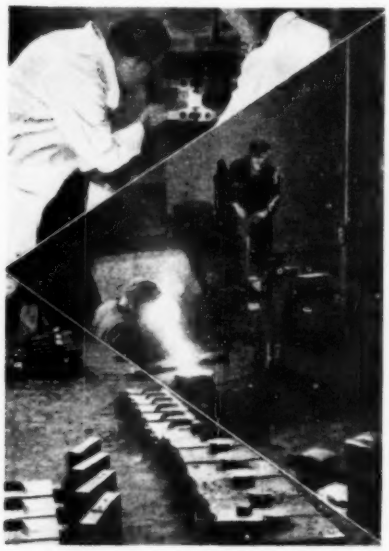

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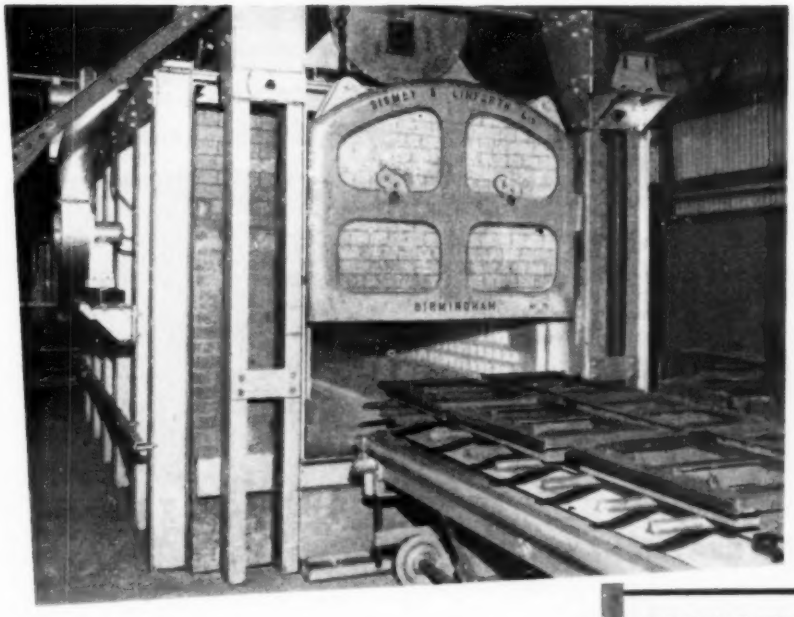

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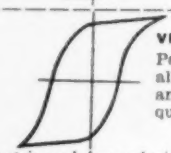

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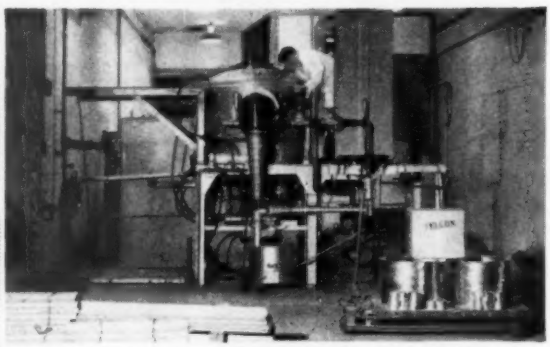

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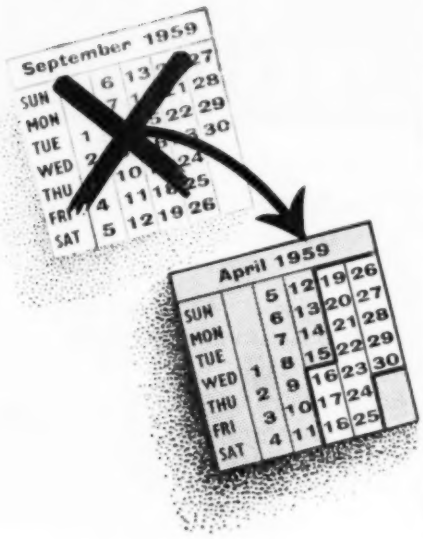

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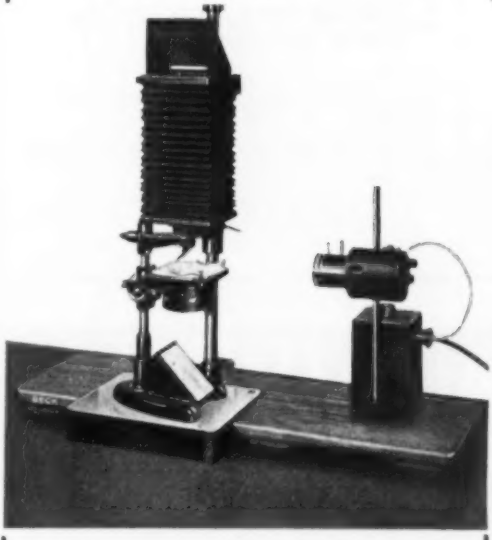

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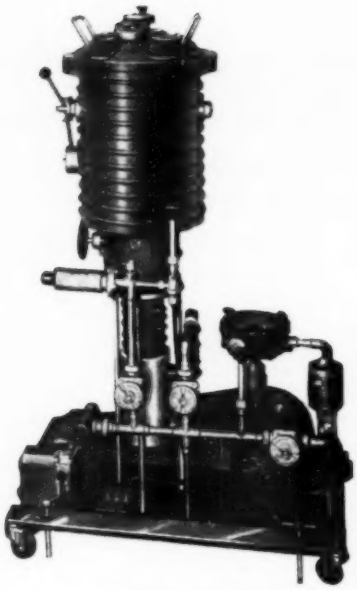

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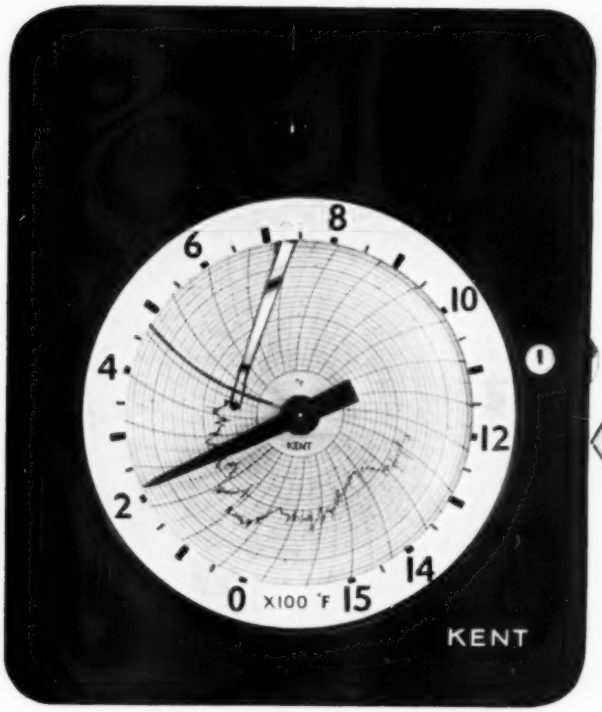

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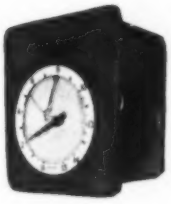

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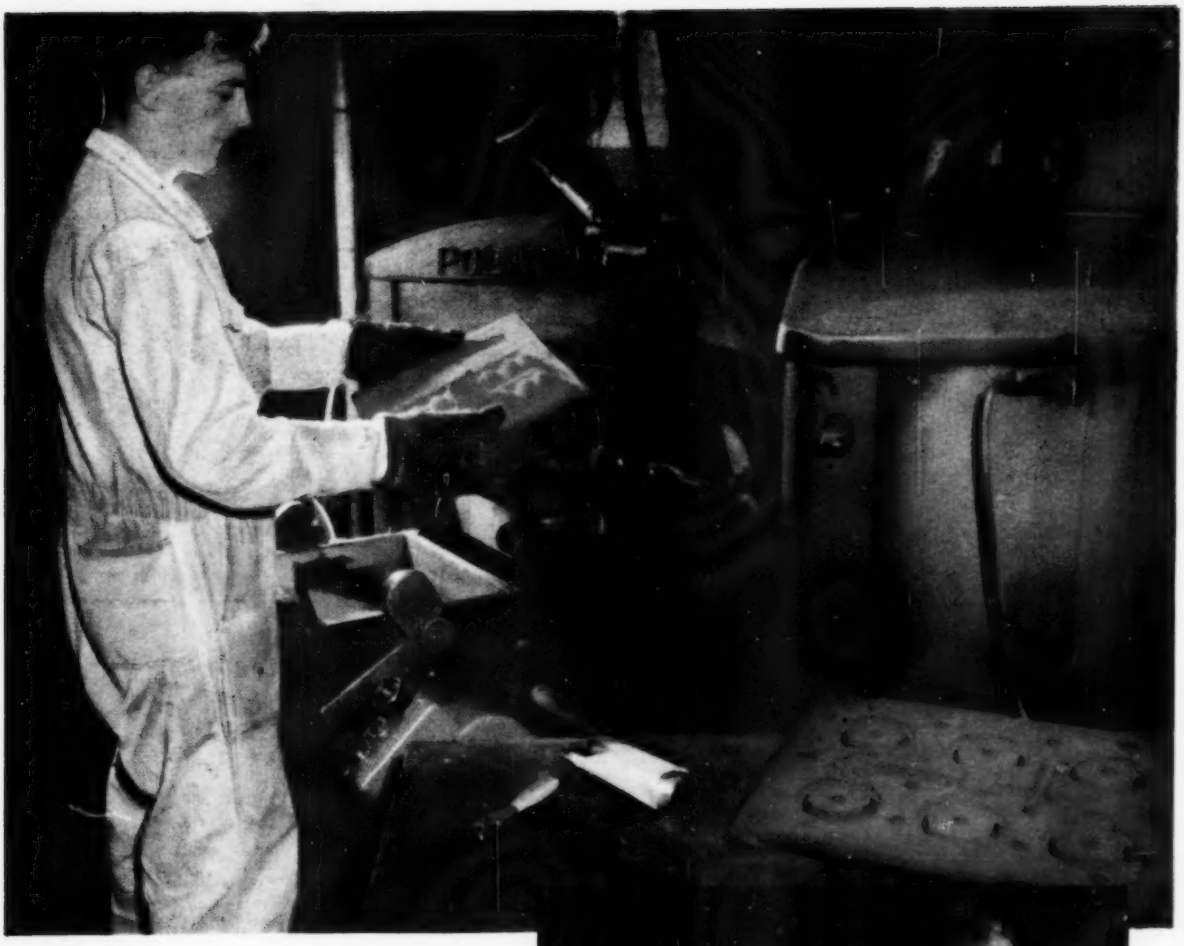

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